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THE COST STRUCTURE OF U.S. RAILROAD INDUSTRY, 1980-81

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The cost structure of U.S. railroad industry, 1980-81

by

Tenpao Lee

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Graduate Faculty in Partial Fulfillment of the

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CHAPTER I. INTRODUCTION

Since 1887, the railroad industry has been regulated by the Federal Government. The major reason for this regulation is that railroads have been considered to be natural economic monopolies. However, the rate of return on net investment of the railroad industry has been very low. During the past three decades, the highest rate of return occurred in 1955 when the railroad industry earned an average of 4.22 percent[3]. Since then, the industry has averaged only 2.6 percent return on net investment. By 1980, earnings had increased to 4.13 percent on net investment but the 1980 cost of capital to the railroad industry was estimated to be 17.8 percent.

In the decade of the 1970s, several major railroad companies declared bankruptcy and the Chicago, Rock Island and Pacific Railroad Company was ordered liquidated. The low earnings of the industry as a whole and the operating losses of several major railroad companies have resulted in continued deterioration of railroad plant and service. Federal regulation was felt to be partially responsible for this situation because such regulations made it impossible for railroads to shed unprofitable operations and to adjust rates to meet intermodal competition. Proposals to improve the earnings performance of the railroad industry include restructuring the railroad industry by reducing the number of companies and miles of track, establishing balanced policies towards the competing modes, and reducing economic regulation of the railroad industry.

In 1976, the Railroad Revitalization and Regulatory Reform Act (4R Act) introduced a new era of regulation which stressed more reliance on competition and cost-based ratemaking for the railroad industry. The concept of revenue adequacy was introduced into railroad ratemaking by the 4R Act and was defined as a level of earnings sufficient to enable a carrier to meet all of its expenses, retire a reasonable amount of debt, cover plant depreciation and obsolescence, and earn a return on investment adequate to attract new capital.

Congress retained the goal of revenue adequacy in The Staggers Rail Act of 1980 as one of several factors to be considered in railroad ratemaking and sought to deregulate railroad rates in competitive markets while maintaining regulatory control over rates and practices applicable to shippers who were without competitive transportation alternatives. The Interstate Commerce Commission (ICC) was charged with the responsibility to maintain reasonable rates where there is an absence of effective competition and where rail rates provide revenues which exceed the amount necessary to maintain the rail system and to attract capital.

Although the 4R Act and The Staggers Rail Act were not directed at any particular commodity carried by railroads, coal is one of the major commodities moved by railroads that has and will be severely affected by the 4R Act and The Staggers Act. Coal shippers are heavily dependent on rail transportation since two thirds of the U.S. coal production is transported by rail. Prior to the early 1970s, the primary factor influencing the level of rail rates on coal to electric utilities had been the substitution of natural gas for coal in electric utility fuel purchases. In an attempt to develop markets for western coal, the western coal-hauling railroads maintained relatively low rates. However, both the supply and demand sides for coal transportation changed during the past decade. The pressure for higher rail rates on coal initially arose on new movements of low sulfur coal out of Montana, Wyoming, Colorado, and other western states, where no established rates existed. From the demand side, natural gas prices increased as shortages developed in the wholesale markets in the 1970s, leading many utilities dependent on natural gas to switch to coal in new steam generating plants. In response to the energy crisis of 1973, Congress passed legislation requiring new steam-fired generating plants to burn coal unless exempted on environmental grounds. There was a sharply increased demand for coal and hence for railroad transportation of coal. As a result, coal has become the dominant commodity carried by railroads In 1982, coal represented 30 percent of all rail car loadings.

Much of the coal transported by railroads is frequently described as "captive"[1] traffic. In February, 1983, the ICC published a decision in Ex Parte No. 347 (Sub-No. 1), Coal Rate Guidelines, Nationwide, proposing a maximum rail rate policy applicable to "captive" coal traffic and trying to achieve the basic objective of revenue adequacy in the railroad industry in accordance with the 4R Act. Under the proposed Coal Rate Guidelines, rail carrier pricing of so called

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[1] Captive traffic is defined as a market where no effective transportation competition exists for shippers.

"captive" coal traffic would be subject to the following four upper constraints:

1. A coal shipper could not be charged more than the "stand-alone cost"[2] of serving its traffic.
2. Captive shippers or receivers would not be required to bear the cost of obvious management inefficiencies.
3. Carriers would generally not be permitted to increase their rates on "captive" coal traffic by more than 15 percent in a single year (after allowing for inflation).
4. Until a rail carrier achieves revenue adequacy, it would be free to adjust its rates unless it violates one of the three constraints listed above.

The theoretical framework in developing the Coal Rate Guidelines is based on the concept of the Ramsey pricing system. The Ramsey pricing system is a method for differential pricing based on demand elasticities. It is designed to apply when marginal costs are less than average costs. Specifically, Ramsey pricing is a mark up above marginal costs on the basis of the inverse demand elasticity to recover total costs. The ICC asserts that the Ramsey pricing system yields economically efficient rates, because the resulting rates do not bias the demand patterns that

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[2] The "stand-alone cost" to any shipper is defined as the cost of serving that shipper alone, as if it were isolated from the railroads' other customers. It represents the level at which the shipper could provide the service itself under all assets valued at current replacement cost.

would be achieved under marginal cost pricing. The implication of the Ramsey pricing system is that the highest mark-up would be charged to the traffic more dependent on the service provided by the railroad industry.

The Impacts of the Coal Rate Guidelines

Executives of the electric utility industry believe that many coal rates will increase dramatically under the proposed Coal Rate Guidelines. They argue that there is little, if any, effective competition for coal transportation. Individual coal mines and steam-fired electrical generating plants are typically served by only one railroad and only a few mines and steam generating plants can use barge transport. Moreover, the quantity and distances hauled usually make truck transport uneconomical. In 1983, the railroad industry earned 3.13 percent return on net investment. However, a 15.7 percent return on net investment was required to achieve revenue adequacy in 1983 [30]. Thus, significantly higher rates would be required if revenue adequacy were to be achieved through the rate mechanism. These potentially higher coal rates would likely have the following impacts:

1. An increase in rail rates on coal would likely lead to an immediate increase in the purchase price of coal since the rail costs accounted for 30 percent of the delivered price of coal. The amount of increase in coal prices, however, depends on the size of the rate change and the demand and supply conditions of coal. Higher coal prices will certainly discourage the use of coal as a fuel source and cause an increasing dependence upon

other energy sources, including uncertain foreign oil sources.

2. As energy legislation requires new generating plants to burn coal unless exempted on environmental grounds, an increase in coal prices will likely result in higher electricity rates to the consuming public.
3. If the Coal Rate Guidelines are implemented with respect to coal traffic, it is expected that similar guidelines will be applied to other so called "captive" commodities. Hence, the impacts of these guidelines on other so called captive commodities, such as grains, fertilizer, chemicals, and other agricultural products should be evaluated before the execution of the Coal Rate Guidelines.

An Alternative of the Coal Rate Guidelines

The proposed Coal Rate Guidelines are based on the goal of achieving revenue adequacy for the railroad industry through higher rates on so called captive traffic. Although revenue adequacy is defined by Congress, the ICC practically needs a standard for regulatory setting. In Ex Parte No. 393, Standards for Determining Railroad Revenue Adequacy, the ICC concluded that the railroad should have the opportunity to achieve earnings sufficient to yield a return on investment equal to the current cost of capital. The return on investment is defined as equation (1.1).

$$ROI = [\ TR - TVC - TFC\ ]\ [\ \text{Net investment}\ ]^{-1} \qquad (1.1)$$

where

ROI = Return on investment,

TR = Total revenue,

TVC = Total variable cost,

TFC = Total fixed cost.

Equation (1.1) implies the following alternatives for achieving a certain level of return on investment:

1. Raise freight rates and hence total revenue, if the demand for the railroad industry is relatively inelastic.
2. Reduce freight rates and increase the quantity hauled and hence the total revenue, providing the demand of the railroad industry is elastic.
3. Reduce the variable costs.
4. Reduce the net investment.
5. Reduce the fixed costs.
6. A combination of the above five alternatives.

The proposed Coal Rate Guidelines, however, focus only on increased rates through the stand-alone pricing to achieve the goal of revenue adequacy of the railroad industry. This solution emphasizes the inelastic demand characteristic of captive coal traffic, but ignores the cost side and the structure of the railroad industry as a crucial part of achieving railroad revenue adequacy.

Although the railroad industry is one of the most intensively studied of all industries by econometricians, none of previous cost studies of the railroad industry adequately describe the current cost structure of the industry because almost all previous cost studies are based on late 1960 and early 1970 railroad data. Since that time, the railroad industry has undergone rapid structural change. Since 1955, over 50,000 miles of track have been abandoned. Much of the remaining system has been rebuilt. The number of railroad companies has declined sharply. Computer technology has been applied to management decision making and new operation rules have been implemented to reduce energy costs. Unit train systems have been introduced into coal, grain, container, and trailor-on-flat-car operations. The current cost structure of the railroad industry is substantially different from that on which previous studies are based. Hence, policy implications based on these cost studies of relatively out-of-date data may have limited value in establishing policies to deal with the revenue adequacy problem of the current railroad industry. Moreover, most previous studies are based on more restrictive functional forms such as the Cobb-Douglas model and fail to include input factor prices as explanatory variables in the cost model. Some studies use the translog cost model to allow for more flexible model specifications. But no study has been found to compare policy implications under different model specifications while model specifications are totally arbitrary. To provide a better basis for policy decision making, the cost models developed in this analysis are based on the latest railroad data and estimation techniques. These models will be used to test the hypothesis that a cost saving policy can, in part, achieve the goal of revenue adequacy for the railroad industry.

The cost behavior of the railroad industry under different scenarios will be described.

CHAPTER II. OBJECTIVES OF THE STUDY

The objectives of this research are to:

1. Develop alternative cost models for the railroad industry.
2. Describe the cost structure of the railroad industry under alternative cost models.
3. Estimate the potential contribution of cost saving policies to revenue adequacy of the railroad industry.

To facilitate these objectives, railroad cost models are developed based on the duality theorem. The cost structure and cost saving policy alternatives are drawn from the results of the estimated cost models of the railroad industry.

CHAPTER III. REVIEW OF THE LITERATURE

The review of literature will be divided into four sections: the first section reviews the methodologies used in empirical cost studies; the second section reviews the methods of the Interstate Commerce Commission in estimating the Rail Cost Scales for cost based rate-making; the third section reviews the econometric studies of the cost structure of the railroad industry; and the final section reviews selected cost studies of other industries which use relevant estimation techniques.

Methods of Cost Estimation

French [17, p.121] groups the empirical methods used in cost estimation as:

a. the accounting method, which mainly involves combining point estimates of average costs into various classes for comparative purposes;

b. the statistical method, which attempts to estimate functional relationship by econometric techniques;

c. the economic-engineering method, which synthesizes production and cost relationship from engineering data or other estimates of the components of the production function; and

d. a combination of the above three methods.

Compared to the other methods, the accounting method is relatively cheap, simple, and easy to understand. However, cost behavior is affected by many factors and the accounting method fails to separate the influence of the individual factors. It provides no evidence of the functional relationship suggested by economic theory. The statistical method, although using some of the same data as the accounting method, is distinguished from the accounting method by its attempts to develop quantitative estimates of cost functions and to test theoretical hypotheses. Two major problems in using statistical methods are the treatment of data and model specification. The economic-engineering method provides a clearer picture of the cost behavior based on technical input-output relationship. It avoids many of the problems encountered in the statistical approach. For example, the economic-engineering method allows costs to be estimated even when historical cost data are not available. However, this method is limited by its higher research cost and many researchers lack the expertise and resources needed to gather the engineering and field data required by this method.

French found that all the methods discussed above contain limitations of analytical power which can not meet the needs of all researchers. The optimal choice of method depends on the objectives of the study and the available funds and data.

The Rail Cost Scales

Almost all railroad cost studies are based on the data published by the Interstate Commerce Commission (ICC) and the Association of American Railroads (AAR). The ICC developed its own method of estimating the Rail Cost Scales for cost based ratemaking. Rail Form A (RFA) was first developed in 1938 by the ICC to ascertain rail costs in connection with the Uniform Class Rates Scale case. The RFA is a formula-based method of estimating rail costs from railroad accounting data that breaks the total costs into various subcomponents of rail operations. The subcomponents include yard switching, road haul, station, special services, and general overhead. The formula then uses different output indicators, such as gross ton-miles and car miles, to construct a linear functional form to estimate average variable costs and average fixed cost of each subcomponent.

Drinka, Baumel, and Miller [15] estimated rail transport costs for grain and fertilizer by simply adjusting published ICC rail cost data based on RFA. Their procedure follows rail cost adjustment methods prescribed by the ICC in "Rail Carload Cost Scales, 1972." They outlined: 1) the adjustment for single-car grain and fertilizer shipments; 2) the adjustment for multiple-car grain and fertilizer shipments; 3) the adjustment of 1972 costs to reflect wage price level changes; and 4) calculation of variable costs. They found that the published freight rates exceeded the estimated rail costs for all sizes of shipments of grain for which rates are published, and the published freight rates exceeded the estimated rail costs for all single-car rail shipments of fertilizer.

Gallagher, DeVol, and Crown [21] developed a multi-regional input-output model to estimate expenditures of the rail industry by using 1972 ICC Rail Cost Scale data. They estimated the interregional differences in railroad expenditures and pointed out that their model would be useful for the study of changes in regional prices and quantity demanded. The input costs were divided into maintenance of way and structures, maintenance of equipment, traffic, transportation, miscellaneous operations, and general overhead. The outputs referred to revenues received for railroad transportation services including: freight, passenger, switching and terminal, express, terminal collection and delivery, substitute service, milk hauling, protective service, demurrage, salvage, tips and red cap service, and water transfers. They found that grand total expenditures by the rail industry were 16.3 billion dollars in 1972 based on this model and that there existed regional differences in spending patterns by railroads.

In response to the provisions of the Railroad Revitalization and Regulatory Reform Act of 1976 (4R Act), the ICC incorporated its prior costing efforts into an overall program to revise the Uniform System of Accounts (USOA) and to develop a successor costing system, the Uniform Rail Costing System (URCS), to RFA [36]. The revised USOA was adopted in 1977 and went into effect on January 1, 1978. The new URCS has recently been completed and is now being introduced as the primary railroad regulatory costing tool. The URCS is a complex set of procedures which transforms reported railroad expense and activity data into estimates of the costs of providing specific services. The URCS estimation procedure consists of three steps. First, a data base containing the expenses and operating statistics is created. The total cost of the railroad is then broken into additive subcomponent expense accounts based on rail operations such as road haul, switching, and general overhead. Each expense account is then related to an output indicator such as gross ton-miles, car miles, and net ton-miles by using correlation and regression techniques. The unit costs of specific services are estimated based on the components of the data base. The total cost of providing a specific movement is estimated based on the unit costs.

Although the URCS does not relate well to any notion of economic costs and does not take account of economic cost and production theory, the URCS remains the most suitable for the purpose of cost based ratemaking. This is because: 1) none of the recent econometric studies permits an adequate breakdown of costs by commodity or equipment type; 2) the ICC is interested in characterizing the structure of rail rates that will follow deregulation; and 3) the results will be distorted if the substantial differences among the terminal and switching costs of boxcars, open top hoppers, covered hoppers, and refrigerated cars are ignored.

Cost Structure of the Railroad Industry

The earlier cost studies of the railroad industry were designed to determine the relationship between full costs and variable costs rather than to estimate the cost structure of the railroad industry. Borts [6] conducted a statistical cross sectional analysis of the variance of freight costs for Class I railroads based on 1950s data. He found that there are two sources of bias in the estimation of the rail cost function from cross section data. One is the incorrect treatment of the firm size of the railroads. He argued that, over the long run, firm size should be a function of traffic level and hence firm size should not be included in in a long run cost function. The second is the regression fallacy which arises because some firms produce a greater output than planned and others smaller than planned. Borts measured the existence of economies of traffic density as follows: first, he divided firms into classes by size and region; then, he performed a covariance analysis on the entire sample to estimate the within-class and between-class cost elasticities; third, he specified a linear cost model which allocated freight operating expense as a function of total loaded and empty freight car-miles and total freight carloads. The within-class cost elasticity is interpreted as a short run cost elasticity and the between-class cost elasticity is interpreted as a long run cost elasticity. If the short run cost elasticity is less than the long run elasticity, Borts suggested that there would be economies of traffic density for the firm. The results indicated that there were economies of traffic density for the southern and western firms, but diseconomies of traffic density for the eastern firms.

Keeler [26] developed a Cobb-Douglas multi-product cost function to estimate a short run rail cost function based on 1968-70 railroad data. The model included a variable to measure the firm size (track mileage) and applied the envelope theorem to solve for the firm size and derived a long run cost curve. Two types of scale economies in the rail industry, returns to traffic density and returns to scale, and excess capacity of each road were estimated. The basic assumptions of the analysis were:

a. The production function of rail industry is a Cobb-Douglas form which can be further interpreted as meaning that the elasticities of substitution among input factors are all unity and the production structure is homothetic so that inputs and outputs can be written separably in a cost function.

b. All factor prices are constant over the cross section which implies the cost function is a function of output levels only.

Keeler found that: 1) the rail industry had substantial economies of traffic density but constant long run returns to scale, and 2) all firms faced excess capacity.

Harris [24] argued that average length of haul should be included as an explanatory variable since using ton-miles as a measure of output implicitly assumes that one ton carried 1000 miles is equivalent to 1000 tons carried one mile. He specified a linear cost function which expressed average cost per net ton-mile as a function of average length of haul, traffic density, and a dummy variable of firm locations. According to his estimates, there are very significant economies of traffic density and economies of average length of haul in the rail freight industry based on 1972-73 railroad data. However, he pointed out that a linear specification is very restrictive.

Sidhu, Charney, and Due [32] developed a linear model to estimate long run average cost functions for Class II railroads. Class II railroads are defined as those with less than $50 million revenues per year. The model specified cost per thousand net ton-miles as a function of traffic density (net ton-miles per miles of line) and distance (average length of haul or mileage of the road). The basic assumptions were: 1) factor input prices were uniform for all roads and hence omitted from the model; 2) costs per ton-mile are not affected by the type of traffic carried. Based on the 1968 and 1973 Class II railroad cross sectional data, they found that:

1. There are substantial economies of traffic density. The estimated cost elasticity with respect to output of a median firm is 0.67. The economies of length of haul are not significant.
2. The minimum efficient traffic density (where economies of traffic density are exhausted) is 1.3 million ton miles per mile.

Harmatuck [23] classified railroad costs into activity categories including maintenance of way, maintenance of equipment, yard expenses, train expenses, and other expenses. He argued that the inflexibility of work rules and the standardization of certain railroad operating procedures make it more appropriate for cost functions to be estimated using activities. A joint translog cost function was estimated based on 1968-70 railroad data by the maximum likelihood techniques. He found that:

1. Many previous cost specifications have imposed inappropriate constraints on the nature of railroad costs.
2. There are substantial economies of traffic density at small tonnage levels but that traffic density economies are substantially reduced as output increases.
3. There are substantial economies of average length of haul.
4. These findings should prove useful in formulating merger

policy.

Caves, Christensen, and Swanson [10] estimated the growth in productivity in the rail industry based on the neoclassical theory of production. They fit a translog cost model to railroad data to estimate the elasticities of total cost with respect to outputs and factor prices. The model specified that total cost is a function of input prices, outputs, and time. The input factors included labor, way and structures, equipment, fuel, and materials. The growth in productivity in the railroad industry was defined as the combined rates of growth of outputs and inputs weighted by their respective elasticities of output. They found that railroad productivity grew at an average rate of 1.5 percent per year during the 1951-1974 period.

Friedlaender and Spady [19] estimated a translog cost function of Class I railroads based on 1968-70 cross section data. The model includes five variable factors, one fixed factor, four technological conditions, and two outputs. They found that:

1. The estimated short run cost elasticity with respect to output is 1.12 which implies negative returns to traffic density in the short run.
2. The estimated long run cost elasticity with respect to output is 0.87 which implies positive returns to firm size in the long run.
3. The estimated elasticity with respect to average length of haul is -0.56 which implies positive returns to average length of haul.

4. Fuel-labor and equipment-labor are substitute inputs. Fuel and equipment are complementary inputs.

Caves, Christensen, and Swanson [11] estimated a generalized translog cost model of Class I railroad based on 1955-74 cross section data. The model includes three input factors: equipment, labor, and fuel. They found that:

1. Class I railroads had positive returns to scale in 1955, 1963, and 1974.
2. The estimated average annual rate of productivity growth was 1.8 percent in 1955-74.
3. All inputs were substitutable among one another, but the estimated elasticity of substitution between labor and fuel was higher than either fuel-equipment or labor-equipment.
4. Fuel was more responsive to the change of its own prices.

Braeutigam, Daughety, and Turnquist [7] estimated a hybrid cost function for a single railroad firm by using time series data to fit a flexible translog model. They called their model a hybrid because they incorporated engineering information (speed of services) to improve model specification. The input factors included labor, fuel, and equipment. Traffic density, length of haul, and firm size were excluded from their model because that the data were obtained from a small bridge railroad with a simple route structure in 1969-77. They found that the hybrid approach did significantly improve the model and the cost function corresponded to a nonhomothetic production structure. A fundamental question they failed to check is whether their empirical results were a well-behaved cost function since a translog cost function will not globally satisfy the economic regularity conditions.

Keeler [25] summarized previous cost studies of the railroad industry and pointed out that:

1. Most of the nation's rail system operates subject to increasing returns to scale and has elements of natural monopoly.
2. At some point between 7 million and 15 million or more net ton-miles per route mile, the cost curves for Class I railroads flatten out and a large part of the traffic in the system flows over this flat part.
3. For very short haul, terminal oriented railroads, the long run cost curve seems to flatten out much sooner.
4. There are considerable economies of longer hauls.
5. There are constant or mildly decreasing returns to larger firm sizes when traffic density is held constant.
6. There is still much to be learned about the structure of the railroad industry. The methods used in earlier studies have several shortcomings including the failure to allow the changing of factor prices, and the use of restrictive models, such as the Cobb-Douglas functional form.

Related Cost Studies

Christensen and Greene [13] provided a typical application of the translog cost function to estimate economies of scale in the U.S. electric power generation industry. They outlined procedures to estimate factor demand elasticities, elasticities of substitution among input factors, and economies of returns to scale. It is not clear whether they estimated a long run or a short run translog cost function. However, since they applied the results to estimate scale economies and used cross sectional data, one can assume that they estimated a long run translog cost function. Christensen and Greene pointed out that, although the translog function provides a second order approximation of an arbitrary cost function, some of the economic regularity conditions of a well behaved cost function will not automatically be satisfied. Therefore, they imposed a constraint on the model to satisfy the requirement of homogeneity of degree one in input prices and tested all other regularity conditions with the estimated results. They found that: 1) there were significant economies of scale for all firms in 1955; and 2) a small number of extremely large firms were operating in the flat area of the average cost curve in 1970.

Bressler [8] suggested that, instead of fitting average functions, the long run cost function might be estimated as an envelope function to the bottom of the cost scale scatter diagram. This is because if a long run cost function was estimated, the results will not hold unless all the firms were operating at a long run equilibrium point and that is a very restrictive assumption.

Cave and Christensen [9] discussed the global properties of flexible functional forms and found that in some cases the translog model performed better, while in other cases the generalized Leontief model performed better. They pointed out that the generalized Leontief model has a larger regular region (region where the economic regularity conditions are satisfied) when the elasticity of substitution is small and the translog model is preferable when the input elasticity of substitution is high. Nevertheless, flexible functional forms other than the translog model have not been used in the railroad cost studies.

Lopez [28] provided a typical application of the generalized Leontief cost model in estimating the derived demand for the inputs in Canadian agriculture. The study indicated that:

1. The generalized Leontief model allows for a nonhomothetic production structure and preserves the same degree of flexibility as the translog model.
2. Continuity and linear homogeneity in prices are the only conditions imposed on the generalized Leontief cost model. All the other conditions of a well-behaved cost function will depend on the actual values of the estimated parameters.
3. Return to scale and technical change can be tested by the model.
4. The model can be reduced to an ordinary Leontief cost model.
5. Input own price elasticity, cross price elasticity, and elasticities of substitution can be estimated by the derived equations.
6. The model can be modified to reflect the characteristics of other industries, such as the railroad industry.

CHAPTER IV. AN ECONOMIC FRAMEWORK OF COST ESTIMATION

This chapter provides an economic framework of cost estimation from the theoretical point of view. The first section discusses the derivation of cost functions. The second section deals with the duality between cost functions and production functions. The third section emphasizes the application of Shephard's lemma to cost estimation. The final section specifies definitions of returns to traffic density, returns to firm size, and returns to average length of haul.

The Derivation of a Cost Function

The best utilization of any particular input combination is a technical rather than an economic problem. Therefore, the production function presupposes technical efficiency and states the maximum output obtainable from all possible input combinations. Cost functions are also based on the assumption that entrepreneurs behave in a cost-minimizing manner; that is, entrepreneurs will always have the ratio of marginal product of input i and input j equal to the price ratio of input i and j. Mathematically, a cost function is the solution of the cost minimization problem for the production of a given output level and can be described as follows:

$$\text{Minimize } C=\Sigma P_i^*X_i+b \qquad (4.1)$$

subject to

$$f(Y,X_1...X_n) \leq 0$$

where,

$f(.) \leq 0$ is the production function, Y is the amount of output level,

X_i is the amount of input i,

P_i is the price of input i,

b is the fixed cost.

If X_i^* is the optimum value of input i in solving equation (4.1), then $X_i^*=X_i^*(P_i,Y)$ which is a function of input prices and output level. As $C^*=\Sigma P_i * X_i^*(P_i,Y)$, total cost is a function of input prices and as well as the output level.

On the other hand, since we are assuming cost minimizing behavior, we can also derive the expansion path function from a production function. The cost function can be derived by reducing the following system of equations to an explicit function of input prices and output level:

$Y=f(X_i)$	production function,	(4.2)
$C=\Sigma P_i * X_i + b$	cost equation,	
$0=g(X_i)$	expansion path function.	

The production function must satisfy the following regularity conditions to ensure that (4.1) and (4.2) have solutions:

a. f is a real valued function of N real variables $X=(X_i\text{'s})$, where $X \geq \underline{0}$ and every finite bundle of inputs gives rise to a finite output.

b. $f(\underline{0})=0$ and if $X^i \geq X^j$, then $f(X^i) \geq f(X^j)$, that is, f is a nondecreasing function in X.

c. f(X) tends to be plus infinity. Every positive output level is producible by some input combination. For every positive integer N, there exists $X^N \geq 0$, such that $f(X^N) \geq N$.

d. f is a right continuous function.

e. f is quasi-concave function and exhibits diminishing returns with respect to any input factors.

Given that a production function satisfies the above regularity conditions and that input prices are strictly positive, a cost function can be derived which will satisfy the following conditions:

a. C is a positive real valued function.

b. C is continuous, differentiable, and tends to plus infinity as Y tends to plus infinity for every $P>0$.

c. C is linear homogeneous in input prices.

d. C is a concave function in input prices for every $Y>0$.

e. C is monotonically increasing in output.

The Duality between Cost Functions and Production Functions

To derive a cost function empirically, we must specify a production function for equation (4.1). Several problems arise in specifing a production function:

1. Production functions are largely unobservable.
2. Production itself is a technical problem per se. This is usually beyond the knowledge of economists.
3. Unless very simple and hence restrictive functional forms for the production functions are assumed (i.e. Cobb-Douglas), the cost function frequently can not be solved explicitly.
4. Even if a cost function is derived, the resulting equation may

not be feasible to estimate.

However, the use of duality between cost functions and production functions allows us to side-step the problems of solving equation (4.1) by directly specifying suitable minimum cost functions rather than production functions.

The duality theorem is based on Minkowski's theorem which states that every closed convex set may equivalently be regarded as the intersection of its supporting half spaces. The duality between cost functions and production functions asserts that: 1) a concave production function yields a cost function homogeneous of degree one in input prices, given specified regularity conditions; 2) a cost function which is homogeneous of degree one in input prices yields a concave production function, given specific regularity conditions; and 3) the cost function derived from a particular production function will in turn yield that production function. Hence, technology may be equivalently represented by a production function which satisfies certain regularity conditions or a cost function which satisfies certain regularity conditions, and the estimation of a well-behaved cost function is equivalent to the estimation of a well-behaved production function. The same economically relevant information can be obtained from either cost function approach or the production function approach.

Empirically, the use of dual approach (cost approach) has the following advantages:

1. The dual approach permits the use of more flexible functional forms which requires imposing fewer restrictive assumptions about

the nature of technology.

2. There is less multicollinearity among input prices than among input quantities.
3. Input prices are more likely to be truly exogenous to firms than are input levels.
4. To estimate input demand and output supply responses, fewer algebraic manipulations are needed for the cost function approach.
5. Data on factor prices, total costs, and output levels are often more readily available than data on input levels.

Shephard's Lemma

Shephard's lemma states that the partial derivatives of a well-behaved cost function with respect to the input prices equal the cost minimizing values for the inputs. As the cost function is homogeneous of degree one in input prices, the input demand function will be homogenous of degree zero in input prices, that is, if all the input prices double, the input shares will remain the same as before.

Shephard's lemma is convenient for deriving the input demand functions and narrows the gap between economic theory and empirical work. Furthermore, for cost functions in logarithm form, Shephard's lemma provides input cost share functions rather than input demand functions.

Returns to Traffic Density, Returns to Firm Size, and Returns to Average Length of Haul

Returns to traffic density, returns to firm size, and returns to average length of haul are important concepts in estimating railroad cost functions.

Returns to traffic density

Returns to traffic density describe the cost savings response to a proportionate increase of traffic level in the short run. The short run concept of returns to traffic density in this analysis assumes that firm size is held constant during the specific period. Mathematically, returns to traffic density can then be obtained by taking a partial derivative of the cost function with respect to output level.

The reasons for the existence of returns to traffic density are:

1. The railroad industry is characterized by a high level of fixed costs and heavy investments in long-lived specialized assets, mainly the capital and maintenance expenses of road property. As route traffic goes up, the fixed cost portion of each unit of output will go down and result in a lower average cost of each unit of output.
2. As traffic density rise, trains tend to get longer, thereby reducing line haul crew costs per ton of freight carried. Train frequencies also rise which allows for better utilization of both labor and equipment.
3. Returns to traffic density can take the form not only of lower costs, but also of better services at the same costs. As higher density allows a railroad to operate more frequent trains, the shippers will experience more frequent and improved service.

Returns to firm size

Returns to firm size describe the cost savings behavior under different levels of firm size as measured by road miles. By holding the same traffic density and average length of haul constant, returns to firm size means that the larger the firm, the lower the average costs. Mathematically, returns to firm size are estimated by taking a partial derivative of the cost function with respect to firm size and holding the traffic density constant. Holding traffic density constant implies that output levels will vary proportionally as the firm size varies. Hence, the same information can be obtained by taking a partial derivative of a cost function with respect to output while holding traffic density constant or by taking a partial derivative with respect to firm size while holding traffic density constant.

The reasons for the existence of returns to firm size are that larger firms are more likely to have better management, information, research and development, and more power to influence market outlets. In addition, there is a practical reason for the railroad industry to have returns to firm size by merging with interlining firms. Long distance railroad services commonly involve movements over the lines of more than one railroad company. As the originating railroad usually keeps the movement on its own line as far as possible to maximize its revenue, the resulting operating costs may be higher than the operating costs over the short line distance of one single merged firm. The large firms usually possess more road miles and are more flexible in route selection and hence may have lower average costs.

Returns to average length of haul

Returns to average length of haul describe the cost savings behavior under different average lengths of haul while holding traffic density and firm size constant. As average length of haul is measured by net ton-miles divided by net tons, returns to average length of haul is derived mathematically by taking a partial derivative of the cost function with respect to net tons. The main reasons for the existence of returns to average length of haul are that the terminal and operating expenses may decrease as average length of haul increases. It is obvious that one ton carried 1,000 miles is not equivalent to 1,000 tons carried one mile. Hence, failure to take into account the returns to average length of haul will bias the estimated coefficients as ton-mile is used as a measure of output. The reason to distinguish returns to firm size from returns to average length of haul is that a large size firm is more likely but may not necessarily have a higher average length of haul than a small size firm. If average length of haul is perfectly associated with firm size, the effects of returns to average length of haul would not be separable from the effects of returns to firm size.

Interaction of returns to traffic density, firm size, and average length of haul

Practically, it is not possible to increase firm size while holding either traffic density or average length of haul constant. The cost behavior for each individual railroad results from the combined effects of returns to traffic density, returns to firm size, and returns to average length of haul. For example, an integrated nationwide railroad will have an advantage over a railroad that must make interline shipments to and from other railroads. The advantage results from: 1) returns to firm size as the nationwide railroad may be more flexible in route selection; 2) returns to average length of haul as unnecessary switches and terminal costs between interlined railroads can be saved and hence aggregate average length of haul goes up; and 3) returns to traffic density as aggregate traffic density may change.

The relationship between firm size and traffic density can be shown on the decreasing section of the U-shaped long run average cost curve in Figure 4.1. The following conclusions can be drawn from this figure:

1. $SRAC_1$ represents the short run average cost curve of a small size firm and $SRAC_2$ represents that of a large size firm. The tangency of the short run and long run average cost curves for a large size firm is located at a flatter position than that of a small size firm. The tangency of $SRAC_1$ at point B is AB/BC while the tangency of $SRAC_2$ at point B' is A'B'/B'C'. As $SRAC_1$ is located at a steeper position, it appears that AB/BC is greater than A'B'/B'C'. Hence, the average cost of a large firm is less responsive to firm size change than that of a small size firm on the long run average cost curve. Similarly, the average cost of a large firm may be less responsive to traffic density change than that of a small size firm on the short run average cost curve if the firm operates at a portion near the long run average cost curve.

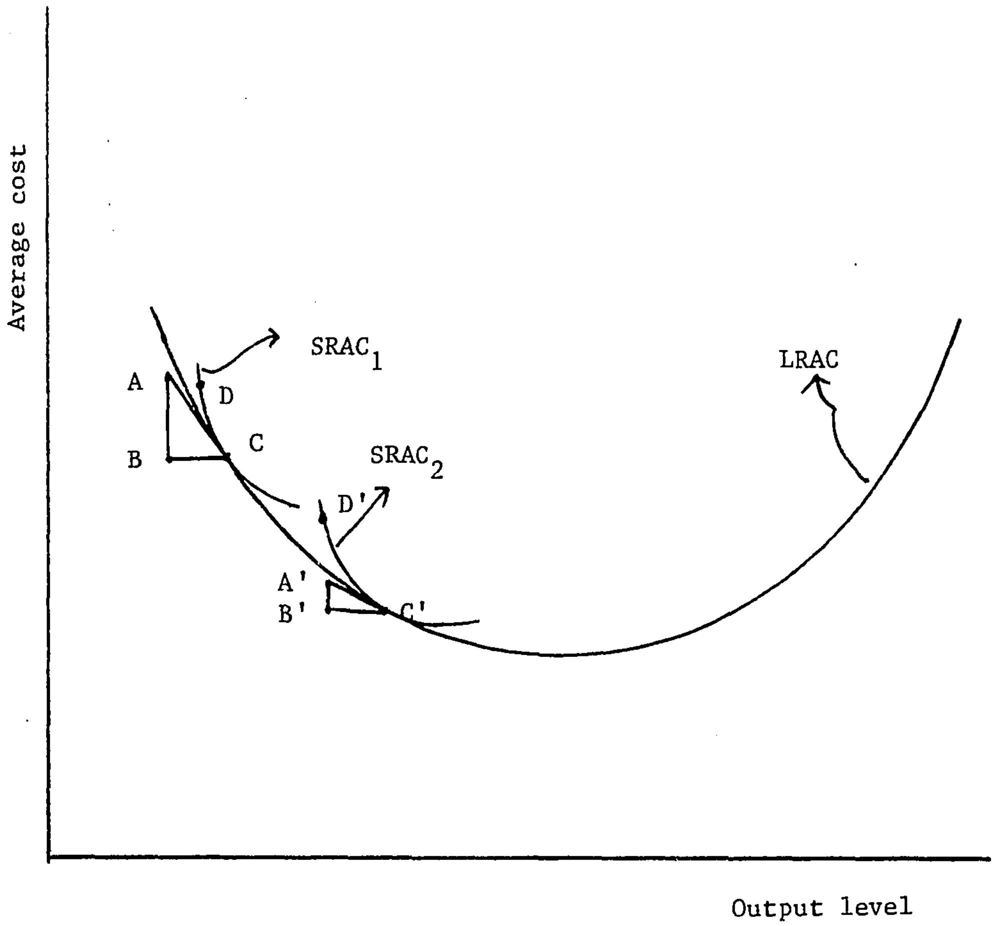

Figure 4.1 The relationship between firm size and traffic density

2. Returns to firm size was defined by holding traffic density constant. A positive return to firm size implies that a firm can lower its average cost by expanding its firm size. However, this does not mean that the firm's optimal size for current traffic density should become larger. In Figure 4.1, assume point D and point D' have the same traffic density. If the firm expands its size from $SRAC_1$ to $SRAC_2$ without changing traffic density, its average cost at point D will fall to the average cost at point D' due to returns to firm size. But at point D, the firm's optimal size should be smaller since the tangency of the short run and long run average cost curves for point D should be steeper and $SRAC_1$ should shift to the left upper to reach the long run equilibrium.

3. If the change of firm size can only shift the short run average cost curve rather than change its shape, a large size firm would have a higher traffic density on the long run average cost curve. Figure 4.2 illustrates that a large firm has higher traffic density on the long run average cost curve. In Figure 4.2, point B is located at a flatter position than point A and hence has a higher traffic density than that of point A. As long as the shape of the short run average cost curves remains the same, the tangency between SRAC and LRAC of large firms, point B', will be located at a flatter position of the short run average cost curve than that of small firms, A', and thereby have a higher traffic density.

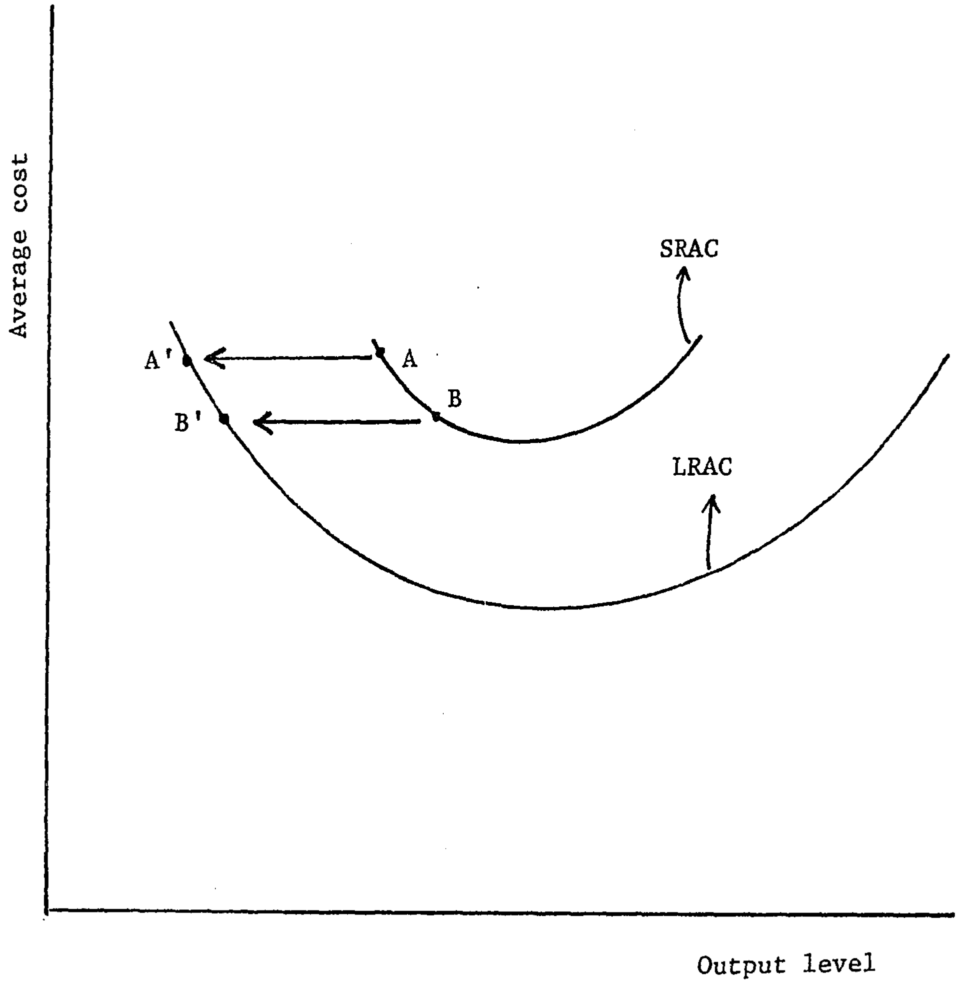

Figure 4.2 The relationship between firm size and traffic density with the same shape of the short run average cost curve

4. If the change of firm size not only shifts the short run average cost curve, but also changes the shape of the short run average cost curve, the cost behavior will be more complicated and difficult to predict. Figure 4.3 provides an illustrate that for the same traffic density with different firm sizes, i.e. point A and point A', it is possible for the large firm to have a higher average cost if the curvature of the short run average cost curve of the large firm is steeper than that of a small size firm.

The current traffic density, firm size, and average length of haul faced by each firm are quite different. Returns to traffic density, to firm size, and to average length of haul are defined as the cost responses to changes in traffic density, firm size, and average length of haul by holding the other two returns constant at the current levels of each individual firm. Therefore, the estimated values of returns to traffic density, returns to firm size, and returns to average length of haul of each individual firm should not be compared, rather the firms should be grouped by size and traffic density to analyze the heterogeneity among the firms cost behavior.

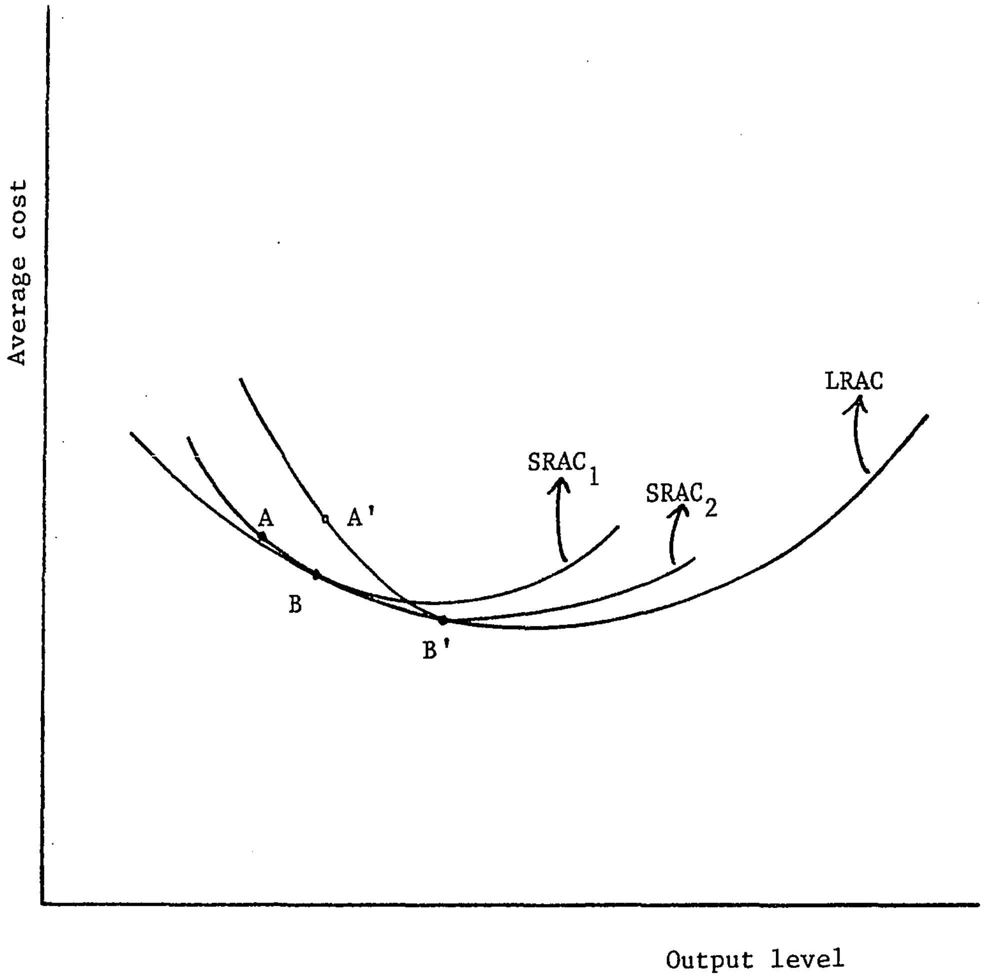

Figure 4.3 The cost behavior of a steeper short run average cost curve

CHAPTER V. THE MODELS

Selection of the Functional Form

A specific functional form which can fulfill the economic regularity conditions and characterize the railroad industry is needed to estimate a rail cost function. Mathematically, there are many functional forms that can meet these conditions. It is possible that the railroad data may fit all or none of those functional forms. It is also possible that several functional forms may have the same level of goodness of fit, but each may have different implications. The fundamental problem is that the true functional form of the rail cost function is unknown and thus it is not possible to estimate a global cost function to explain the cost behavior perfectly. Based on Taylor's expansion theorem, however, it is possible to estimate a local approximate cost function for the railroad industry.

Assume that the true cost function is f(x) with x as an independent variable and the true functional form of f(x) is unknown. Taylor's expansion theorem states that it is possible to express any arbitrary function f(x) in a polynomial form as equation (5.1) provided that f(x) has finite, continuous derivatives up to the desired n degree at the expansion point x_0:

$$f(x) = f(x_0) + f'(x_0)(x-x_0) + \ldots + f^{(n)}(x_0)(x-x_0)^n/n! + R_n \qquad (5.1)$$

where R_n denotes the remainder.

The form of the polynomial and the size of the remainder, R_n, will depend on the value of n where n is the order of the highest derivative in the polynomial function. If terms of higher than nth order are neglected in approximating the true cost function, then the higher the nth order, the more accurate the approximation of the true cost function.

For a multivariate cost function, Taylor's expansion becomes more complicated as shown in equation (5.2):

$$f(X) = f(X^0) + \Sigma f_i(X^0)(x_i - x_i^0) + 1/2\Sigma\Sigma f_{ij}(X^0)(x_i - x_i^0)(x_j - x_j^0) + \ldots + R_n \qquad (5.2)$$

where $X=(x_1,\ldots x_n)$ is an n component vector and X^0 is the expansion point.

Table 5.1 provides a summary of the most commonly used functional forms for cost estimation. With the exception of the generalized Cobb-Douglas and generalized concave functions, it can be shown that: 1) both the Cobb-Douglas and Constant Elasticity of Substitution (CES) functions are first order approximations of Taylor's expansion of an arbitrary function; 2) the translog, generalized Leontief, and quadratic functions are second order approximations of Taylor's expansion of an arbitrary function; and 3) the Cobb-Douglas and CES functions are special cases of the translog function, and hence the translog function is more general than the Cobb-Douglas and CES functions.

As discussed in chapter three, economic regularity conditions require that the cost function be homogeneous of degree one in input prices. The quadratic function obviously violates this regularity condition. The generalized Cobb-Douglas and generalized concave functions will not be homogeneous of degree one in input prices unless the cost

Table 5.1 Commonly used functional forms for cost estimation[a]

Functional form[b]	Restrictions for linear homogeneous
1. Cobb-Douglas	
$\ln C = a_o + \Sigma a_i \ln X_i$	$a_1 + \ldots a_n = 0$
2. Constant Elasticity of Substitution (CES)	
$C = a_o + \Sigma a_i X_i$	$a_o = 0$
3. Generalized Leontief	
$C = a_o + \Sigma a_i X_i^{.5} + \Sigma\Sigma a_{ij} X_i^{.5} X_j^{.5}$	$a_i = 0$
4. Translog	
$\ln C = a_o + \Sigma a_i \ln X_i + \Sigma\Sigma a_{ij} \ln X_i \ln X_j$	$a_1 + \ldots a_n = 0$ $a_{ij} = 0$
5. Generalized Cobb-Douglas	
$\ln C = a_o + \Sigma\Sigma a_{ij} \ln(X_i + X_j)/2$	$\Sigma\Sigma a_{ij} = 1$
6. Quadratic	
$C = a + \Sigma a_i X_i + \Sigma\Sigma a_{ij} X_i X_j$	
7. Generalized Concave	
$C = \Sigma\Sigma X_i f(X_i/X_j) a_{ij}$	f is a known concave function

[a] Adapted from: [20, p.238].

[b] C = Total costs and X_i = Price of input i or output i.

function is written as a separable function for output and input prices. If output-input prices are separable, the functional form inherently assumes that the production structure is homothetic which is more restrictive than the translog and generalized Leontief functions.

Functional forms of the third order approximation are much more complicated especially for a multivariate cost function. A second order translog cost function of three input prices, one output, and one firm size indicator will have 21 regressors while a third order translog cost function of the same number of independent variables will have 56 regressors. Hence, a heuristic decision is to approximate the cost function at the second order level.

Theoretically, we can not tell if the translog model is better than the generalized Leontief model. Similarly, even though we can develop a sophisticated functional form other than the translog and generalized Leontief functions, we can not prove that the new functional form is better than either the translog or generalized Leontief functions.

The translog and generalized Leontief functions are also referred as flexible functional forms as no prior restrictions on the elasticities of substitution among input factors are imposed. In this analysis, both the translog and generalized Leontief will be estimated and the results of the two models will be compared.

The Translog Model

The translog cost function for the railroad industry is specified as equation (5.3).

$$\begin{aligned}\ln C = {} & b_0 + b_L L + b_K K + b_F F + b_Y Y + b_D D + b_{LL} L^2 + b_{LK} LK \\ & + b_{LF} LF + b_{LY} LY + b_{LD} LD + b_{KK} K^2 + b_{KF} KF + b_{KY} KY \\ & + b_{KD} KD + b_{FF} F^2 + b_{FY} FY + b_{FD} FD + b_{YY} Y^2 + b_{YD} YD \\ & + b_{DD} D^2 + b_N N + b_{Year} Year + b_{D1} D1 \qquad (5.3)\end{aligned}$$

where

C = total costs,

L = ln(labor price),

K = ln(capital price),

F = ln(fuel price),

Y = ln(output level),

D = ln(traffic density),

N = ln(average length of haul),

D1 = 1 if firm size < 1,000 road miles and traffic density > 10

= 0 otherwise,

Year = 1 for 1981,

= 0 for 1980,

$b_{subscripts}$ are parameters.

Economic regularity conditions require that the cost function be homogeneous of degree one in input prices which implies the following restrictions for the translog cost model:

$$b_L + b_K + b_F = 1,$$

$$b_{LY} + b_{KY} + b_{FY} = 0,$$

$$b_{LD} + b_{YD} + b_{FD} = 0,$$

$$b_{LL} + b_{LK} + b_{LF} = 0,$$

$$b_{KK} + b_{LK} + b_{KF} = 0,$$
$$b_{FF} + b_{LF} + b_{KF} = 0. \tag{5.4}$$

Nonnegativity of all input prices and output levels is automatically satisfied since anti-logarithms are always positive. All the other regularity conditions required of a well-behaved cost function including monotonically increasing in input prices, concavity in input prices, and nondecreasing-in-output levels will depend on the actual values of the estimated parameters. The monotonicity condition is satisfied if the fitted cost shares are all positive. The concavity of the cost function is satisfied if the Hessian matrix is negative semidefinite. Nondecreasing-in-output is satisfied if the partial derivative of the cost function with respect to output level is positive.

Shephard's lemma states that the partial derivatives of the cost function with respect to the input prices equal the cost minimizing values for the inputs. Hence, based on Shephard's lemma, a cost share function of input i can be derived by taking the partial derivative of the translog cost function with respect to its input price i. Let S_i represents the cost share of input i. The cost share functions are:

$$S_F = b_F + b_{LF}L + b_{KF}K + 2b_{FF}F + b_{FY}Y + b_{FD}D$$
$$S_L = b_L + b_{LF}F + b_{LK}K + 2b_{LL}L + b_{LY}Y + b_{LD}D$$
$$S_K = b_K + b_{LK}L + b_{KF}F + 2b_{KK}K + b_{KY}Y + b_{KD}D \tag{5.5}$$

The elasticities of substitution in terms of the cost function developed by Uzawa [37] are defined in equation (5.6) as:

$$e_{ij} = (CC_{ij}) \;/\; (C_iC_j) \tag{5.6}$$

where subscripts on C indicate a partial derivative of the cost function with respect to input price i and e_{ij} is the elasticity of substitution between input i and input j.

For the translog cost function, the elasticity of substitution between input i and input j are specifically defined as equation (5.7).

$$\begin{aligned} e_{ij} &= b_{ij}/(S_i S_j) + 1, \\ e_{ii} &= (b_{ii} + S_i(S_i - 1))/S_i^2 \end{aligned} \tag{5.7}$$

The own price elasticity of demand for the ith factor is defined as:

$$E_i = e_{ii} S_i \tag{5.8}$$

Returns to traffic density (RD), as shown in equation (5.9), are obtained by taking a partial derivative of the cost function with respect to the output level and subtracting from unity.

$$\begin{aligned} RD = 1 - (&b_Y + b_D + b_{LY}L + b_{LD}L + b_{KY}K + b_{KD}K \\ &+ b_{FY}F + b_{FD}F + 2b_{YY}Y + b_{YD}Y + 2b_{DD}D) \end{aligned} \tag{5.9}$$

A positive (negative) value of RD implies an increasing (decreasing) return to traffic density for the firm and a weighted average of all individual firms based on firms' output levels is estimated for the returns of traffic density of the railroad industry.

Returns to firm size (RS), as shown in equation (5.10), are obtained by taking a partial derivative of the cost function with respect to the output level while holding the traffic density constant and subtracting from unity. As holding the traffic density constant implies that output levels will vary proportionally to the amount of firm size change, the same information can be obtained by taking a partial derivative of the cost function with respect to either output level or firm size.

$$RS = 1 - (b_Y + b_{LY}L + b_{KY}K + b_{FY}F + 2b_{YY}Y + b_{YD}D) \qquad (5.10)$$

A positive (negative) value of RS implies an increasing (decreasing) return to firm size for the firm and a weighted average of all individual firms based on firms' output level is estimated for the returns to firm size of the railroad industry.

Returns to average length of haul (RN) are derived by taking a partial derivative of the cost function with respect to average length of haul. As the average length of haul is approximated for the first order as a dummy variable to shift the cost curve in the translog cost model, the estimated returns to average length of haul equal the estimated parameter of the term of average length of haul, b_N.

To allow a simultaneous change of traffic density, firm size and average length of haul, we take a total derivative of the translog cost function with respect to traffic density, firm size, and average length of haul. The net effect is defined as equation (5.11).

$$d(AC) = (RD)\ dD + (RS)\ dS + (RN)\ dN \qquad (5.11)$$

Because a cost function corresponds to a homothetic production structure if and only if the cost functional form can be written as a separable function in its ouput level and factor prices, we can test homotheticity of the cost function by testing $b_{Yi}=0$ and $b_{Di}=0$ for all input i.

A homothetic cost function can be a homogeneous function if and only if the elasticity of cost with respect to output is constant. Hence, we can test the homogeneity by testing if $b_{Yi}=0$, $b_{Di}=0$, $b_{YD}=0$, $b_{DD}=0$, and $b_{YY}=0$.

Suppose all parameters of the second order terms are equal to zero, then the translog will be reduced to Cobb-Douglas. Hence, we can test Cobb-Douglas against translog by testing if all parameters of the second order terms equal zero.

In equation (5.7), if $b_{ij}=0$, the elasticity of substitution between input i and input j will equal unity. If all $b_{ij}=0$ for input i $\neq$ input j, then the translog will be reduced to a CES function. Hence, we can test the CES model against the translog by testing if all $b_{ij}=0$.

The Generalized Leontief Model

The generalized Leontief model can be specified as follows:

$$\begin{aligned} C = {} & b_{LL}P_LY + b_{LF}P_L^{.5}P_F^{.5}Y + b_{LK}P_L^{.5}P_K^{.5}Y + b_{FF}P_FY + b_{FK}P_F^{.5}P_K^{.5}Y + b_{KK}P_KY \\ & + b_{LY}P_LY^2 + b_{KY}P_KY^2 + b_{FY}P_FY^2 + b_{LD}P_LYD + b_{KD}P_KYD + b_{FD}P_FYD \\ & + b_{LN}P_LYN + b_{KN}P_KYN + b_{FN}P_FYN \end{aligned} \tag{5.12}$$

where

C = total costs,

P_L = price of labor,

P_K = price of capital,

P_F = price of fuel,

Y = output level,

D = traffic density,

N = average length of haul,

$b_{subscript}$ = parameters.

Homogeneity of degree one in input prices is automatically satisfied in the generalized Leontief cost model. All the other regularity conditions of a well-behaved cost function will depend on the actual values of estimated parameters, b_{ij}'s.

The input demand functions, as shown in equation (5.13), can be derived directly by applying Shephard's lemma to equation (5.12).

$$X_L = \left(\frac{1}{2} b_{LK} \frac{P_K}{P_L}^{.5} + \frac{1}{2} b_{LF} \frac{P_F}{P_L}^{.5} + b_{LY} Y \right.$$
$$\left. + b_{LD} D + b_{LN} N + b_{LL} \right) Y$$
$$X_K = \left(\frac{1}{2} b_{LK} \frac{P_L}{P_K}^{.5} + \frac{1}{2} b_{KF} \frac{P_F}{P_K}^{.5} + b_{KY} Y \right.$$
$$\left. + b_{KD} D + b_{KN} N + b_{KK} \right) Y$$
$$X_F = \left(\frac{1}{2} b_{LF} \frac{P_L}{P_F}^{.5} + \frac{1}{2} b_{KF} \frac{P_K}{P_F}^{.5} + b_{FY} Y \right.$$
$$\left. + b_{FD} D + b_{FN} N + b_{FF} \right) Y \qquad (5.13)$$

Dividing both equation (5.12) and equation (5.13) by its output level, Y, an average cost function and input-output ratio functions can be shown as equation (5.14) and equation (5.15).

$$AC = b_{LL}\,P_L + b_{LF}\,P_L^{.5}\,P_F^{.5} + b_{LK}\,P_L^{.5}\,P_K^{.5} + b_{FF}\,P_F + b_{FK}\,P_F^{.5}\,P_K^{.5}$$
$$+ b_{KK}\,P_K + b_{LY}\,P_L\,Y + b_{KY}\,P_K\,Y + b_{FY}\,P_F\,Y + b_{LD}\,P_L\,D$$
$$+ b_{KD}\,P_K\,D + b_{FD}\,P_F\,D + b_{LN}\,P_L\,N + b_{KN}\,P_K\,N + b_{FN}\,P_F\,N \qquad (5.14)$$

$$\frac{L}{Y} = \frac{1}{2}\,b_{LK}\left(\frac{P_K}{P_L}\right)^{.5} + \frac{1}{2}\,b_{LF}\left(\frac{P_F}{P_L}\right)^{.5} + b_{LY}\,Y$$
$$+ b_{LD}\,D + b_{LN}\,N + b_{LL}$$

$$\frac{K}{Y} = \frac{1}{2}\,b_{LK}\left(\frac{P_L}{P_K}\right)^{.5} + \frac{1}{2}\,b_{KF}\left(\frac{P_F}{P_K}\right)^{.5} + b_{KY}\,Y$$
$$+ b_{KD}\,D + b_{KN}\,N + b_{KK}$$

$$\frac{F}{Y} = \frac{1}{2}\,b_{LF}\left(\frac{P_L}{P_F}\right)^{.5} + \frac{1}{2}\,b_{KF}\left(\frac{P_K}{P_F}\right)^{.5} + b_{FY}\,Y$$
$$+ b_{FD}\,D + b_{FN}\,N + b_{FF} \qquad (5.15)$$

The own price elasticities are defined as equation (5.16)

$$E_i = \frac{\partial X_i}{\partial P_i}\,\frac{P_i}{X_i} = \frac{Y}{2X_i}\sum b_{ij}\left(\frac{P_j}{P_i}\right)^{.5} \qquad (5.16)$$

The cross price elasticity between input i and price j is defined as equation (5.17).

$$E_{ij} = \frac{\partial X_i}{\partial P_j}\,\frac{P_j}{X_i} = -\,\frac{Y}{2X_i}\,b_{ij}\left(\frac{P_j}{P_i}\right)^{.5}, \; i \neq j \qquad (5.17)$$

The elasticities of substitution among input factors are defined as equation (5.18).

$$e_{ij} = \frac{E_{ij}}{S_j} \qquad (5.18)$$

Similar to the translog cost model, returns to traffic density are obtained by taking a partial derivative of equation (5.14) with respect to output level and are defined as equation (5.19).

$$RD = -(b_{LY}\ P_L + b_{KY}\ P_K + b_{FY}\ P_F + b_{LD}\ P_L/S + b_{KD}\ P_K/S + + b_{FD}\ P_F/S)\ \frac{Y}{AC} \tag{5.19}$$

where S represents firm size.

Returns to firm size, as shown in equation (5.20), are obtained by taking a partial derivative of the generalized Leontief cost function with respect to output level while holding the traffic density constant.

$$RS = -(b_{LY}\ P_L + b_{KY}\ P_K + b_{FY}\ P_F)\ \frac{Y}{AC} \tag{5.20}$$

Returns to average length of haul, as shown in equation (5.21), are obtained by taking a partial derivative of the generalized Leontief cost function with respect to average length of haul.

$$RN = -(b_{LN}\ P_L + b_{KN}\ P_K + b_{FN}\ P_F)\ \frac{N}{AC} \tag{5.21}$$

To allow a simultaneous change of traffic density, firm size and average length of haul, we take a total derivative of the generalized Leontief cost function with respect to traffic density, firm size, and average length of haul. The net effect is defined as equation (5.22).

$$d(AC) = (RD)\ dD + (RS)\ dS + (RN)\ dN \tag{5.22}$$

The following hypotheses can be tested by a generalized Leontief model:

a. The cost function will be homothetic if b_{iY}, b_{iD}, and b_{iN} are equal to zero for all input i.

b. The cost function will reduce to an ordinary Leontief model if all $b_{ij}=0$ for input i $\neq$ input j.

CHAPTER VI. THE DATA

This chapter describes the data, the data sources, and the treatment of the data. All the data used in the analysis are listed in the Appendix for reference.

Data Sources

Table 6.1 provides a summary of all data sources used in this analysis. All the railroad companies in our sample data are classified as Class I railroads based on a three year average of operating revenues. Effective January 1, 1978, Class I railroads are defined as those railroad companies with operating revenue of $50,000,000 or more.

The '<u>Analysis of Class I Railroads</u>' was published for the year of 1980 and 1981 by the Association of American Railroads (AAR) and are not available for the previous or later years. Hence, our analysis will be restricted to the data of the years of 1980 and 1981.

There were 35 Class I railroads in both 1980 and 1981. All but one Class I railroad company generated more than 95 percent of their total gross ton-miles from freight transportation. The Long Island R.R. Co. was the only Class I railroad company that had more passenger gross ton-miles than freight gross ton-miles. Since firms with relatively large amounts of passenger transportation are quite different from firms with a large share of freight transportation and since our purpose is to estimate freight transportation costs, the Long Island R.R. Co. was eliminated from our sample data and the data base will include the remaining 34 Class I railroads. Table 6.2 lists the names and initials of the 34 Class I railroad companies in our sample.

Table 6.1 Summary of data sources

Data source	Processing agency	Data element
Analysis of Class I Railroads, 1980 and 1981 [1,2].	Association of American Railroads, (AAR).	Average number of employee, total labor costs, freight labor costs, freight labor benefits, fuel prices, freight fuel costs, freight operating expenses, miles of road operated, freight net ton-miles, freight tons (net tons).
Yearbook of Railroad Facts, 1983 [3].	AAR.	Fuel price index, labor price index, rail cost index.
Transportation Statistics for the U.S. 1980 and 1981 [33,34].	Interstate Commerce Commission, (ICC).	Total fixed charges.
Uniform Railroad Costing System, 1980 Railroad Cost Study, (URCS) [35].	ICC.	Capital prices.

Table 6.2 Index to railroads

Road initial and region	Railroad name
East	
BO	Baltimore & Ohio R.R. Co.
BLE	Bessemer & Lake Erie R.R. Co.
BM	Boston & Maine Corp.
CO	Chesapeake & Ohio Ry. Co.
CRC	Consolidated Rail Corp.
DH	Delaware & Hudson Ry. Co.
DTI	Detroit, Toledo & Ironton R.R. Co.
EJE	Elgin, Joliet & Eastern Ry. Co.
GTW	Grand Trunk Western R.R. Co.
NW	Norfolk & Western Ry. Co.
PLE	Pittsburgh & Lake Erie R.R. Co.
WME	Western Maryland Ry. Co.
South	
CLIN	Clinchfield R.R. Co.
FEC	Florida East Coast Ry. Co.
ICG	Illinois Central Gulf R.R. Co.
LN	Louisville & Nashville R.R. Co.
SCL	Seaboard Coast Line R.R. Co.
SRS	Southern Railway System
West	
ATSF	Atchison, Topeka & Santa Fe Ry. Co.
BN	Burlington Northern Inc.
CNW	Chicago & North Western Transportation Company
CMSP	Chicago, Milwaukee, St. Paul & Pacific R.R. Co.
CS	Colorado & Southern Ry. Co.
DRGW	Denver & Rio Grande Western R.R. Co.
DMIR	Duluth, Mesabi & Iron Range Ry. Co.
FWD	Fort Worth & Denver Ry. Co.
KCS	Kansas City Southern Ry. Co.
MKT	Missouri-Kansas-Texas R.R. Co.
MP	Missouri Pacific R.R. Co.
SLSW	St. Louis Southwestern Rjy. Co.
SOO	Soo Line R.R. Co.
SP	Southern Pacific Transportation Co.
UP	Union Pacific R.R. Co.
WP	Western Pacific R.R. Co.

Data Treatment

As all the data are derived from accounting reports, some data modifications were needed to fit the data to the models.

Total freight costs are defined as total freight operating expenses plus total freight fixed charges. Total freight operating expenses are obtained directly from AAR reports. Total fixed charges are obtained from ICC reports and were divided into freight fixed charges and passenger fixed charges which were based on the ratio of freight gross ton-miles and passenger gross ton-miles. Average costs are defined as total costs divided by total net ton-miles.

Output level is measured by total net ton-miles. The main reason for using net ton-miles rather than gross ton-miles is that the real output of a railroad is net ton-miles of freight, not the weight of the locomotives and cars.

Firm size is measured by road miles. The main reason for using road miles rather than track miles is that railroads are constrained to operating within their road miles rather than track miles.

Traffic density is defined as output level divided by firm size. Average length of haul is defined as output level divided by net tons carried.

Labor prices equal total labor costs divided by average number of employees. Total freight labor costs are the sum of freight labor costs and labor benefits. Hence, the amount of labor used in freight can be obtained by dividing total freight labor costs by labor prices.

The amount of fuel used in freight is obtained by dividing freight fuel costs by fuel prices.

Capital prices are obtained directly from the URCS report of 1980. URCS estimates cost of capital rates for road and equipment separately. The road capital rate is based on the total interest payments of road debt, plus apportionment of interest payments not directly assignable to road or equipment, divided by the total outstanding road debt, plus an apportionment of outstanding debt not directly assignable to road and equipment. The equipment capital rate is based on the total interest payments on equipment debt, plus an apportionment of interest not directly assignable to road or equipment debt, divided by the total outstanding equipment debt, plus an apportionment of outstanding debt not directly assignable to road or equipment. A composite cost of capital rate is then estimated based on a weighted average of road cost of capital rate and equipment cost of capital rate.

Total freight costs of capital is estimated by subtracting freight labor costs and freight fuel costs from total freight costs. The amount of capital used is then obtained by dividing total freight capital costs by the capital index. Since capital prices are not available for the year of 1981, we assume that each firm has the same capital price as in the year of 1980 for 1981.

A Description of the Data

Sampling distributions and correlation coefficients among variables are tested to describe the variations of data among firms. Table 6.3 presents the tested results and the following points are drawn based on Table 6.3:

Table 6.3 Sampling distribution of the data

Variable	Year 1980	Year 1981	Correlation coefficient with firm size
Average costs in cents per net ton-mile	3.55 (63.7)[a]	4.03 (67.7)[a]	-0.22 (0.07)[b]
Fuel price in dollars per gallon	0.83 (7.2)	1.02 (5.5)	-0.05 (0.67)
Labor price in dollars per employee-year	24,512 (6.8)	26,629 (6.7)	0.09 (0.45)
Capital price in percent rate	7.77 (31.4)	7.77 (31.4)	-0.10 (0.40)
Firm size in road miles	5,228 (116)	5,181 (116)	1.00 (0.00)
Output level in millions of net ton-miles	26,577 (122)	26,768 (126)	0.96 (0.00)
Traffic density in millions of net ton-miles per road mile	5.22 (50.5)	5.31 (54.7)	-0.04 (0.72)
Average length of haul in miles	257 (12.7)	257 (12.8)	0.55 (0.00)

[a] Numbers in brackets are percent coefficients of variation.

[b] Numbers in brackets are levels of significance.

- Average costs among firms are quite different as the coefficient of variation ranges between 64 and 68 percent. The relationship between firm size and average costs is not significant, but large size firms tend to have a lower average costs as the correlation coefficient between average costs and firm sizes is negative.
- Fuel-price variations among firms are not significant. However, large size firms tend to have lower fuel prices.
- Labor price variations among firms are not significant, but large size firms tend to pay higher wage rates.
- Capital price variations among firms are significant. Large size firms tend to have lower prices.
- Firm sizes ranged from 201 road miles to 27,374 road miles and hence the coefficient of variation is 116 percent.
- There is a positive relationship between firm size and output level. Large size firms usually produce more net ton-miles.
- Traffic density variations among firms are relatively significant, but traffic density is not related to firm size.
- The variations of average length of haul among firms are insignificant. However, there is a positive relationship between average length of haul and firm size.

CHAPTER VII. ESTIMATION PROCEDURES

Rail cost estimation procedures are divided into two parts: the first is the estimation of the translog cost model, and the second deals with the generalized Leontief cost model.

Estimation of the Translog Cost Model

The seemingly unrelated regression technique developed by Zellner [39] is adopted to estimate the cost functions and cost share functions as a multivariate system. The seemingly unrelated system has two characteristics that are useful for this estimation: first, all the independent variables are on the right hand side of the equations, and second, the equations are conceptually related to one another and are treated as a single system.

As a practical matter, the seemingly unrelated regression technique is a two-stage estimation procedure. In the first stage, the variance of the error in each single equation and covariances among errors are obtained by estimating each single equation using ordinary least squares (OLS) technique. In the second stage, the system of seemingly unrelated equations is treated as a single large equation and is estimated by using the generalized least squared estimation technique.

The gain in efficiency (lower variance) yielded by the seemingly unrelated regression estimation over the OLS estimation increases directly with the correlation between the disturbances from the different equations and inversely with the correlation between the different sets of explanatory variables. There are two cases in which the seemingly unrelated regression estimation method is equivalent to the equation-by-equation application of OLS. The first case occurs when the covariances among equations are equal zero. The second case occurs when the identical set of independent variables appear in each equation. Nevertheless, if restrictions across equations are imposed, for example, restriction of symmetry across equations, OLS estimation is no longer efficient even though all cost share equations contain the same explanatory variables on the right hand side.

To avoid the problem created by singularity of the contemporaneous covariance matrix, one of the share equations is dropped before carrying out the second stage of the seemingly unrelated regression technique. The resulting estimates are asymptotically equivalent to maximum likelihood estimates, and are invariant to which equation is deleted at the second stage.

The specific procedures of hypothesis testing are:

1. By using the seemingly unrelated regression technique, the entire system is estimated without imposing any restrictions on the system. Then, the results are used to test whether the cost function is homogeneous of degree one in input prices, and the cost share functions are symmetric across related parameters.
2. By using the seemingly unrelated regression estimation, the whole system is re-eatimated with the restrictions of homogeneity of degree one in input prices and symmetry across cost share equations. The results are then used to test for homotheticity of the production structure, homogeneity of output level, the Cobb-Douglas model against the translog model, and

the constant elasticity of substitution (CES) model against the translog model.

3. All other regularity conditions of a well-behaved cost function, i.e. monotonically increasing in input prices, concave in input prices, and nondecreasing in output levels, are tested for each individual firm except concavity which is only tested at sample mean values. Testing concavity is a cumbersome matter and is usually ignored by empirical studies. However, concavity is intrinsic to the cost theory and to the validity of the results. It is important that concavity be tested.
4. Estimated cost shares, factor own price demand elasticities, elasticities of substitution among input factors, short run returns to traffic density, long run returns to firm size, returns to average length of haul, and average costs per net ton-mile are calculated based on the results in the second step.

Estimation of the Generalized Leontief Cost Model

Similar procedures used in the previous section are applied to estimate the generalized Leontief cost model. However, the whole system will include input demand functions and a cost function rather than cost share functions and a cost function.

The specific procedures of estimation and hypothesis testing are as follows:

1. As total costs equal the summation of input quantities times input prices, the cost function is dropped in the estimation

procedure to avoid the problem of singularity of the covariance matrix.

2. By using the seemingly unrelated regression technique, the whole system is estimated without imposing any restrictions. The results are then used to test the symmetry across input demand equations.
3. By using the seemingly unrelated regression technique, the whole system is re-estimated with the restriction of symmetry across input demand equations. The results will be used to test the homotheticity of the production structure and the ordinary Leontief model against the generalized Leontief model.
4. All economic regularity conditions of a well-behaved cost function are tested by using a similar procedure in testing the translog cost model.
5. Estimated cost shares, factor own price elasticities, input demands, elasticities of substitution among input factors, short run returns to traffic density, returns to average length of haul, returns to firm size, and average costs per net ton-mile are estimated based on the results in the third step.

CHAPTER VIII. THE RESULTS OF RAILROAD COST ESTIMATION

The results of the railroad cost estimation are presented in four sections: the first section presents the results of the translog cost model; the second section presents the results of the generalized Leontief cost model; the third section presents a comparison between the results of the translog and the generalized Leontief cost models; and the final section presents a comparison between the results of our study and other studies.

The Results of the Translog Cost Model

Table 8.1 presents the results of the major tests for goodness of fit of the railroad data for the translog cost model. The following conclusions are drawn from Table 8.1:

- Economic theory requires that cost functions be homogeneous of degree one in input prices and symmetric across cost share functions. Therefore, the statistical test of the compatibility of these restrictions with the data will help interpret the goodness of the translog model representation of a global railroad cost function. The test of homogeneity of degree one in input prices is to test the condition required by equation (5.4). The test of symmetry across cost share functions is equivalent to testing $b_{ij} = b_{ji}$ for all input $i \neq j$. The results in Table 8.1 indicate that both homogeneity and symmetry for the translog model are accepted at a level of significance of one percent and are rejected at a level of significance of five

Table 8.1 Summary of test results of goodness of fit of the translog model

Tests	F-values	Prob. > F
Tests for economic regularity conditions:		
1. Homogeneity in input prices	2.21	0.045
2. Symmetry, given homogenity	1.94	0.033
Tests for production structure[a]:		
1. Homotheticity	4.55	0.012
2. Homogeneity in output	7.91	0.000
Tests for reduced models[a]:		
1. Cobb-Douglas	13.02	0.000
2. Constant Elasticity of substitution (CES)	7.23	0.000

[a] The restrictions of homogeneity of degree one in input prices and symmetry across cost share equations are imposed.

percent. These results imply that the translog cost model is not strongly accepted as a suitable functional form to "globally" represent the cost structure of the railroad industry. However, as the translog cost model is used as a local approximation of an arbitrary cost function at the second order level, one may not expect the restrictions of homogeneity and symmetry to automatically hold because the higher order terms are ignored by the model. By ignoring the higher order terms, the estimated translog cost model will inherently result in truncation errors. This will limit the use of the translog model in extrapolating outside the data range. Therefore, interpretation of the data must be tempered since: 1) the translog model can not globally represent the railroad cost function; and 2) the ability to extrapolate outside the data range of the translog model is limited.

The translog cost function does not constrain the structure of production to be homothetic, nor does it impose restrictions on the elasticities of cost with respect to output. But these restrictions can be tested statistically. If any of the restrictions are not rejected, it is preferable to adopt a simplified model rather than the complex translog model. The test of homotheticity is to test $b_{Yi}=0$ for all input i. The test of homogeneity in output is to test all the parameters of second order term of output equal zero given the condition of homotheticity. The results indicate that the production structure is not homothetic and the production function is not homogeneous in output. Both hypotheses are rejected at a level of significance of one percent. Therefore, a homothetic production structure will not be considered in our model specification.

- Both the Cobb-Douglas and CES models are special cases of the translog model. The translog model will reduce to a Cobb-Douglas model if all parameters of the second order terms equal zero. The translog will reduce to a CES model if all $b_{ij} = 0$ for input $i \neq j$. The results indicate that the translog model can not be reduced to either the Cobb-Douglas or CES model. Both the Cobb-Douglas and CES models are rejected as a suitable cost functional form for the railroad industry at a level of significance of one percent.

Other regularity conditions of a well-behaved cost function, including concavity and monotonicity in input prices, and nondecreasing in output level, depend on the actual values of the estimated parameters. Violation of these regularity conditions would indicate a potential specification problem with a cost model.

Table 8.2 presents the estimated parameters of the translog cost model. To test curvature (concavity) conditions, the Hessian matrix, as specified in equation 8.1, has been estimated at sample mean values.

$$|H| = \begin{vmatrix} C_{FF} & C_{FL} & C_{FK} \\ C_{FL} & C_{LL} & C_{LK} \\ C_{FK} & C_{LK} & C_{KK} \end{vmatrix} = \begin{vmatrix} \frac{C}{P_F^2}(-S_F+b_{FF}) & \frac{C}{P_F P_L} b_{FL} & \frac{C}{P_F P_K} b_{FK} \\ & \frac{C}{P_L^2}(-S_L+b_{LL}) & \frac{C}{P_L P_K} b_{LK} \\ & & \frac{C}{P_K^2}(-S_K+b_{KK}) \end{vmatrix}$$

Table 8.2 Estimated coefficients of the translog cost model

Variables	Coefficients	Estimate	t-ratios
Intercept	b_0	0.93	0.40
L	b_L	-0.13	-0.40
K	b_K	1.37	4.55
F	b_F	-0.24	-1.81
Y	b_Y	-0.94	-2.72
D	b_D	-0.56	-0.90
LL	b_{LL}	-0.04	-0.43
LK	b_{LK}	0.10	3.83
LF	b_{LF}	-0.06	-3.56
LY	b_{LY}	-0.02	-1.69
LD	b_{LD}	-0.05	-1.91
KK	b_{KK}	-0.09	-3.81
KF	b_{KF}	-0.01	-0.86
KY	b_{KY}	$0.93*10^{-2}$	0.92
KD	b_{KD}	0.14	0.90
FF	b_{FF}	0.07	3.59
FY	b_{FY}	0.01	2.99
FD	b_{FD}	0.03	3.73
YY	b_{YY}	0.09	3.83
YD	b_{YD}	0.06	3.12
DD	b_{DD}	-0.30	-5.25
Year	b_{Year}	0.05	1.21
N	b_N	-0.10	-2.09
D1	b_{D1}	0.92	4.24

The weighted $R^2 = 0.96$.

$$= \frac{C^3}{P_F^2\ P_L^2\ P_K^2} \begin{vmatrix} -S_F+b_{FF} & b_{FL} & b_{FK} \\ & -S_L+b_{LL} & b_{LK} \\ & & -S_K+b_{KK} \end{vmatrix} \quad (8.1)$$

Since $\frac{C^3}{P_F^2\ P_L^2\ P_K^2}$ is positive, the sign of the Hessian matrix is determined by the estimated parameters in Table 8.2 and the estimated cost shares of each input. The estimated cost shares at sample mean values are 12 percent, 48 percent, and 40 percent for fuel, labor, and capital respectively. By substituting the estimated cost shares and the results in Table 8.2 into equation (8.1), the estimated Hessian matrix can be shown as equation (8.2):

$$|H| = \begin{vmatrix} -0.05 & -0.06 & -0.01 \\ -0.06 & -0.49 & 0.10 \\ -0.01 & 0.10 & -0.49 \end{vmatrix} \quad (8.2)$$

Equation (8.2) is a negative semidefinite Hessian matrix. Hence, the estimated translog cost function satisfies the concavity conditions.

The monotonicity condition is satisfied if the fitted cost shares are all positive. Our results indicate that all the estimated cost shares are positive and thereby meet this requirement.

The nondecreasing-in-output requirement is satisfied if $\frac{\partial \ln C}{\partial \ln Y}$ is positive. This requirement is similar to the estimation of returns to traffic density. Our results indicate all firms satisfy this condition.

The suitability of the translog functional form for estimating cost of the railroad industry is accepted for the following reasons:

1. The tests of the compatibility of homogeneity of degree one in input prices and symmetry across the cost share functions with the data are accepted at a one percent level of significance but rejected at a five percent level. This implies that the translog cost model can not globally represent the cost function of railroad industry and is limited in extrapolating outside the data range.
2. Economic regularity conditions for a well-behaved cost function are satisfied by the results of the constrained translog cost model. Hence, the translog model can locally represent the railroad cost function.
3. The test of the production structure for the railroad industry indicates that the production structure is neither homothetic nor homogeneous. The translog model is flexible in specifying the production structure and is able to represent a nonhomothetic and nonhomogeneous production structure.
4. Both the Cobb-Douglas and CES models are rejected as a suitable functional form to represent the railroad industry.
5. Overall, the estimated translog model results in a weighted R^2 of 96 percent. R^2 is called the coefficient of determination. A weighted R^2 of 96 percent means that the estimated translog model accounts for 96 percent of the variation of cost behavior, and 4 percent remains unexplained.

In summary, the translog cost model is accepted as a suitable functional form to locally represent the cost function of the railroad industry.

Table 8.3 presents the estimated average costs per net ton-mile, returns to traffic density, and returns to firm size for each individual firm, as well as current firm size measured by miles of road and traffic density. The following is an analysis of the results in Table 8.2 and Table 8.3:

Estimated average cost

- Since each individual firm faces different cost conditions, the estimated average costs per net ton-mile for the industry are weighted averages of all firms in the population. The estimated 1980 weighted average costs are 3.34 cents per net ton-mile with a 44 percent coefficient of variation while the estimated 1981 weighted average costs are 3.86 cents per net ton-mile with a 52 percent coefficient of variation. The actual average costs of the industry were 3.55 cents per net ton-mile with a 64 percent coefficient of variation in 1980 and 4.03 cents per net ton-mile with a 68 percent coefficient of variation in 1981. A comparison between the estimated average costs and actual average costs of the industry indicates that the estimated average costs of the industry are smaller than the actual average costs of the industry and also have smaller coefficients of variation.
- Firms with lower than average costs are characterized by small size and high traffic density. For example, the Clinchfield R.R.

Table 8.3 Current firm size, traffic density, estimated average cost, returns to traffic density, and returns to firm size for each individual firm based on the translog cost model for Class I railroad companies, 1980 and 1981

Year	Railroad company	Current firm size in road miles	Current traffic density in million ton-miles per mile	Estimated average cost in cents per net ton-miles	Estimated returns to traffic density	Estimated returns to firm size
1980	ATSF	12,161	6.0	2.5	0.37	-0.04
	BO	5,280	4.4	2.8	0.37	0.20
	BLE	205	10.8	3.0	0.87	0.37
	BM	1,393	1.8	4.4	0.27	0.73
	BN	27,361	5.1	3.1	0.26	-0.11
	CO	4,754	6.2	2.3	0.45	0.09
	CNW	9,379	3.1	3.1	0.23	0.23
	CMSP	3,901	3.0	3.1	0.30	0.38
	CLIN	296	13.7	1.7	0.89	0.23
	CS	678	10.7	2.3	0.76	0.19
	CRS	18,902	4.4	2.8	0.26	0.01
	DH	1,746	2.2	3.7	0.30	0.61
	DRGW	1,848	6.0	2.6	0.53	0.25
	DTI	540	2.8	7.1	0.46	0.70
	DMIR	441	5.1	4.2	0.62	0.52
	EJE	201	3.2	8.9	0.58	0.81
	FEC	492	5.9	2.5	0.65	0.45
	FWD	1,181	6.5	2.1	0.59	0.28
	GTW	929	3.7	4.5	0.48	0.52
	ICG	8,566	3.8	3.4	0.29	0.18
	KCS	1,663	5.9	2.5	0.54	0.26
	LN	6,570	5.9	2.7	0.42	0.06
	MKT	2,175	3.8	3.0	0.42	0.39
	MP	11,521	5.2	2.7	0.34	0.02

Table 8.3 (continued)

Year	Railroad company	Current firm size in road miles	Current traffic density in million ton-miles per mile	Estimated average cost in cents per net ton-miles	Estimated returns to traffic density	Estimated returns to firm size
1980	NW	7,448	6.5	2.3	0.43	0.01
	PLE	270	5.3	5.2	0.67	0.57
	SLSW	2,448	4.4	2.8	0.43	0.32
	SCL	8,740	4.2	3.2	0.32	0.13
	SOO	4,445	2.3	2.9	0.23	0.45
	SP	10,966	6.0	2.6	0.38	-0.03
	SRS	10,210	5.3	2.7	0.35	0.03
	UP	8,614	9.2	1.9	0.50	-0.14
	WM	1,180	1.8	4.9	0.28	0.74
	WP	1,435	3.2	4.1	0.41	0.51
1981	ATSF	12,366	6.1	2.9	0.37	-0.05
	BO	5,230	4.4	3.2	0.37	0.20
	BLE	205	10.3	3.9	0.86	0.39
	BM	1,317	1.7	5.0	0.27	0.75
	BN	27,374	5.7	3.7	0.28	-0.15
	CO	4,856	5.9	2.8	0.44	0.10
	CNW	8,256	3.4	3.9	0.27	0.22
	CMSP	3,925	2.7	3.4	0.28	0.42
	CLIN	296	14.8	1.6	0.91	0.20
	CS	678	12.5	2.0	0.80	0.14
	CRS	18,420	4.3	3.2	0.25	-0.02
	DH	1,722	2.0	4.2	0.28	0.64
	DRGW	1,802	6.4	2.8	0.55	0.23
	DTI	623	2.4	7.9	0.41	0.73
	DMIR	436	5.1	4.9	0.62	0.52

Table 8.3 (continued)

Year	Railroad company	Current firm size in road miles	Current traffic density in million ton-miles per mile	Estimated average cost in cents per net ton-miles	Estimated returns to traffic density	Estimated returns to firm size
1981	EJE	201	2.7	12.4	0.55	0.87
	FEC	492	5.8	2.8	0.64	0.46
	FWD	1,181	8.3	1.8	0.65	0.20
	GTW	972	3.8	5.0	0.48	0.50
	ICG	7,963	3.8	3.8	0.29	0.19
	KCS	1,663	5.9	2.8	0.54	0.26
	LN	6,538	6.2	3.0	0.43	0.04
	MKT	2,174	3.9	3.3	0.42	0.38
	MP	11,272	5.2	3.1	0.34	0.02
	NW	7,803	6.3	2.8	0.41	0.01
	PIE	270	4.8	6.5	0.65	0.61
	SLSW	2,384	5.6	2.8	0.49	0.23
	SCL	8,563	4.2	3.6	0.31	0.14
	SOO	4,433	2.2	3.3	0.21	0.48
	SP	10,962	5.9	3.1	0.37	-0.02
	SRS	10,057	5.3	3.0	0.35	0.03
	UP	9,096	8.2	2.3	0.47	-0.11
	WM	1,175	1.6	5.9	0.26	0.78
	WP	1,435	2.9	4.8	0.38	0.54

Co. (CLIN) had only 296 road miles in operation but hauled 13.7 million net ton-miles per road mile. The estimated average cost for CLIN was only 1.7 cents per net ton-mile in 1980. Firms with higher average costs are also characterized by small size but low traffic density. For example, the Detroit, Toledo & Ironton R.R. Co. (DTI) had 540 road miles in operation but had only 2.8 million net ton-miles per road mile. The estimated average cost for DTI was 7.1 cents in 1980. For the same traffic density, large size firms had lower average costs than small size firms. For example, the GTW and the ICG had the same traffic density in 1981, but the estimated average cost of the ICG was 1.2 cents per ton-mile lower than that of GTW. The ICG and GTW had 7,683 and 972 road miles respectively.

The following conclusions can be made from these results: 1) cost performance is the result of the combination of firm size and traffic density; 2) for the same traffic density, large size firms have higher returns to firm size and hence lower average costs; 3) small size firms with a high traffic density may also have low average costs.

Returns to traffic density

Using equation (5.9), returns to traffic density are estimated while holding firm size constant at the 1980 and 1981 levels. Hence, returns to traffic density should not be compared among individual firms unless their firm sizes are identical or near identical. For the industry, however, it is reasonable to compare returns to traffic density of small size firms with large size firms. The interpretation of an estimated value of returns to traffic density of say 0.5, is that a one percent increase in current traffic density will result in a 0.5 percent decrease in average cost per net ton-mile. The estimated results indicate that:

1) The weighted average returns to traffic density of the industry were 0.36 in both 1980 and 1981 which means the industry lowered its average cost per net ton-mile by 0.36 percent for each one percent increase in average traffic density.
2) All firms had positive returns to traffic density which means all firms lowered their average costs by increasing the output level on their existing road miles.
3) Small size firms typically had higher returns to traffic density which means a one percent increase in the traffic density of small size firms reduced their average costs proportionally more than that of large size firms. The estimated correlation coefficient between firm size and returns to traffic density is -0.53. This implies that small size firms generally had higher returns to traffic density and are more elastic to traffic density change than large size firms. The result is consistent with the cost behavior of a U-shaped long run average cost curve (refer to Figure 4.1).
4) The range of the estimated returns to traffic density was from 0.22 to 0.91.

• Returns to traffic density is derived by taking a partial derivative of the translog cost function with respect to output level. Therefore, returns to traffic density is a function of current input prices, current output level, and current traffic density. The value of estimated returns to traffic density will change as long as current input prices, current output level, and current traffic density change. Hence, the value of the estimated returns to traffic density is valid only for the 1980-1981 price and output levels.

<u>Returns to firm size</u>

• Using equation (5.10), returns to firm size are estimated while holding traffic density constant. Holding the traffic density constant implicitly assumes that output level will vary proportionally as firm size varies. The interpretation of an estimated return to firm size of say 0.5, is that a one percent increase in firm size will result in a 0.5 percent decrease of average cost per ton-mile. The estimated results indicate that:

1) The weighted average returns to firm size of the railroad industry were 0.05 and 0.04 in 1980 and 1981 respectively. This implies that a one percent increase in average firm size lowered the average industry ton-mile cost by 0.04 to 0.05 percent.

2) Most firms had a positive return to firm size which means that most firms lowered their average costs by increasing their size if the same traffic density was held constant.

3) For the same traffic density, small firms had higher returns to firm size than larger firms. For example, the traffic densities of the Grand Trunk Western R.R. Co. (GTW) and the Illinois Central Gulf R.R. Co. (ICG) were the same in 1981. The GTW and ICG had 972 and 7,963 road miles in 1981 respectively. The estimated returns to firm size were 0.50 for the GTW and 0.19 for the ICG. This is probably because the railroad industry has a decreasing long run average cost curve and the ICG is located at a flatter position than that of GTW. The result is consistent with the implications of Figure 4.1.

4) For the railroad industry, small firms usually had higher returns to firm size than that of large size firms, although traffic densities were not constant across firms. The estimated correlation coefficient between firm size and returns to firm size is -0.71. This means that small size firms were more responsive to firm size than large firms, which is consistent with the implications derived from Figure 4.1.

The results indicate negative returns to firm size for the Atchison, Topeka & Santa Fe Ry. Co. (ATSF), the Burlington Northern Inc. (BN), the Southern Pacific Transportation Co. (SP), and the Union Pacific R.R. Co. (UP). As the first order condition states that returns to firm size is a function of current input prices, output level, firm size, and traffic density, a negative return to firm size means that these four large firms would have increased their average costs by increasing the number of road miles holding the traffic density constant. However, the Consolidated Rail Corp. (CRS), also a large size firm of 18,902 road miles, had a positive return to firm size. Therefore, a negative return to firm size does not necessarily mean large firms are operating at an increasing section of long run average cost curve. As shown in Figure 4.3, a negative return to firm size might mean the firms with negative returns to firm size are operating on the portion of a short run average cost curve with a steeper shape.

Returns to average length of haul

Returns to average length of haul are estimated by taking a partial derivative of the cost function with respect to net tons while holding the traffic density and firm size constant. As there is limited interaction between input prices and average length of haul, average length of haul is treated as a dummy variable and is approximated at the first order level to have more degrees of freedom in the translog model. Returns to average length of haul are assumed to shift the cost curve rather than change its shape. Hence, the estimated return to average length of haul is the estimated parameter of the term of average length of haul and therefore, it is not possible to estimate returns to average length of haul for individual railroad companies. The results in Table 8.2 indicate a negative sign for returns to average length of haul which means that an increase of one percent of average length of haul will result in a decrease of 0.10 percent of average cost per ton-mile. The t-ratio confirms that the effect of average length of haul on cost behavior is significant at a level of 5 percent.

Estimated optimal firm size

The optimal firm size can be estimated for current traffic density by using the envelope theorem. However, as the estimated optimal firm size is obtained by setting the partial derivative of the cost function with respect to firm size equal to zero, the meaning of the estimated optimal firm size is limited due to the following:

1) Since the Taylor series expansion is an approximation of an arbitrary function, the desirable properties will hold locally at the sample data means, and may not necessarily have desirable properties when extrapolated very far outside the data range. If current firm sizes of railroad companies are well-above the optimal firm sizes for current traffic densities, all calculations of optimal firm size entail extrapolating along an estimated cost function and are likely to be sensitive to the specifications of the cost model. If this is the case, the estimated optimal firm size may not be meaningful in its absolute value; rather it may only imply a directional change.

2) Mathematically, the value of anti-logarithm of an expected

value of a variable in logarithm form will not equal the expected value of that variable, that is, antilog $E(\log X) \neq E(X)$. Hence, there is a natural bias in using an anti-logarithm transformation.

3) The purpose of the study is to estimate a cost function rather than a dynamic adjustment function for firm size. As adjustment costs of firm size are not included in the translog model, the amount of adjustment will have less meaning than the direction of adjustment.

Nevertheless, we estimate the optimal firm size for the industry. The results indicate that the optimal railroad firm size for the current traffic density is smaller than the current firm sizes. The absolute value of the estimated optimal firm size of 54 road miles of track per firm is, in itself, meaningless. However, the direction of the estimate suggests that, for current traffic density levels, there is excess capacity in the railroad industry, but the model is limited in estimating the amount of excess capacity. Moreover, average costs of the railroad industry will decline if the size of the firms decline for current traffic density level.

Minimum efficient traffic density

Similar to the estimation of optimal firm size, one may also estimate a minimum efficient traffic density for the railroad industry. The minimum efficient traffic density is defined as the level at which returns to traffic density are exhausted, i.e.

cost elasticity with respect to output level equals unity. By using equation (5.9), minimum efficient traffic density is estimated while setting returns to traffic density equal zero. The estimated minimum efficient traffic density for the railroad industry is 7.1 million net ton-miles per route mile of track based on Table 8.2. This means that returns to traffic density would be exhausted at a level of 2.4 train-miles per day for a 100-car train of 300 shipping days a year or 3.2 train-miles per day for a 75-car train in 1980-81. This suggests that many branch rail lines will not likely achieve the minimum efficient level of traffic. The actual traffic density of the railroad industry in 1981 was 5.3 million net ton-miles per route mile of track. The interpretation of the estimated minimum efficient traffic density is also limited as it is extrapolated from a local approximate cost function. The conclusion is that average costs of the railroad industry will decline if traffic densities increase for current firm size levels.

Interaction of returns to firm size, traffic density and average length of haul

Practically, railroad firms can not change their firm size without changing their traffic density and average length of haul. The changing of firm size, traffic density, and average length of haul are usually related and not separable. A total differentiation of the translog cost function will permit the estimation of cost behavior under heterogenous changes of traffic density, firm size, and average length of haul. As shown in equation (5.11), the net effect on the average cost of the railroad industry is the summation of the effects of returns to firm size, returns to traffic density, and returns to average length of haul. To estimate the net effects of returns to firm size, traffic density, and length of haul, it is necessary to assume a set of simultaneous changes in these variables. For example, if current traffic density, firm size, and average length of haul of the railroad industry increase one percent simultaneously, the net effect on average cost can be estimated by equation (5.11):

$$\begin{aligned} d(AC) &= (RD)\ dD + (RS)\ dS + (RN)\ dN \\ &= (0.05)\ (1.0) + (0.36)\ (1.0) + (0.10)\ (1.0) \\ &= 0.51 \end{aligned}$$

The estimated net effect indicates that a one percent increase in traffic density, firm size, and average length of haul for the railroad industry will result in a 0.51 percent decrease in average cost per net ton-mile. Therefore, these estimates suggest that fewer but larger firms operating fewer total miles of track would have lower total costs than the 1980 and 1981 cost levels.

Production structure of the railroad industry

The duality between cost and production functions suggests that similar information can be obtained based on either the production structure or cost structure. The production structure of the railroad industry is characterized by its elasticities of substitution among input factors. The elasticity of substitution is defined as the proportionate rate of change of the input ratio divided by the proportionate rate of change of the input price ratio. It is a measure of the responsiveness of the optimal proportions among the firm's inputs to changes in their relative prices. A positive (negative) elasticity of substitution between two inputs means that the two inputs are substitute (complementary) inputs. A substitute input means that an input can be replaced by another input in the production process and have the same effects on production. For example, capital and labor are substitutable inputs in maintaining the road tracks. A complementary input means that the use of one unit of one input must combine the use of a certain amount of another input to complete the production. For example, crew members and fuel are necessarily combined to complete a trip. By using equation (5.7), elasticities of substitution among fuel, labor, and capital are estimated based on the results of Table 8.2. Table 8.4 presents the average of elasticities of substitution of all firms and their percent coefficients of variation.

Table 8.4 Estimated elasticities of substitution of the railroad industry based on the translog cost model

Year	Capital-labor	Capital-fuel	Labor-fuel
1980	1.568 (1.6)[a]	0.739 (10.4)	-0.123 (150)
1981	1.576 (1.4)	0.762 (10.1)	-0.077 (219)

[a] Numbers in brackets are percent coefficients of variation.

The following conclusions can be drawn based on Table 8.4:

- The estimated elasticity of substitution between labor and capital indicates that labor and capital can be substituted for each other given the current technology. A one percent increase of relative labor-capital price will result in a decrease of 1.57 percent in the ratio of labor and capital used. The result is consistent with the historical experience of the railroad industry In the past decade, the number of employees of the railroad industry has been reduced from 526,061 in 1972 to 378,906 in 1982. One of the likely reasons for the decline in railroad employment is that more capital was hired to substitute for labor in the railroad industry.
- Similarly, a one percent increase in the relative capital-fuel price will result in a decrease of 0.75 percent in the ratio of capital and fuel used. The results suggest that fuel saving techniques will continue to be employed by railroad industry if fuel prices continue to rise relative to capital prices since, within a relative range, fuel and capital substitute for each other.
- Whether labor and fuel are substitute inputs or complementary inputs is indeterminate. The industry average is a negative value of the estimated elasticity of substitution between labor and fuel, but the estimated elasticity of substitution between labor and fuel for individual firms ranges from -0.56 to 0.09 and coefficients of variation are 150 and 219 for 1980 and 1981

respectively.

- The coefficients of variation are relatively small for the elasticities of substitution between labor-capital and capital-fuel. This implies that firms are likely to have similar flexibility to changes in labor and capital prices.
- The production structure of 1980 and 1981 are very similar. Technology change may not be significant between these two years.

Cost structure

Table 8.5 presents the estimated average cost shares of all firms and their coefficients of variation.

Table 8.5 Estimated percent input cost shares of the railroad industry based on the translog cost model

Year	Capital	Labor	Fuel
1980	40.4 (8.7)[a]	48.0 (11.4)	11.6 (21.4)
1981	40.0 (9.1)	47.9 (11.8)	12.1 (21.4)

[a] Numbers in brackets are percent coefficients of variation.

The following conclusions can be drawn from Table 8.5:

- The major cost component for the railroad industry is labor. About 48 percent of the total costs is spent for labor. Capital and fuel shares are 40 percent and 12 percent respectively. Compared with the cost structure of early nineteen seventies, the cost structure of 1980 and 1981 are quite different. For example, in 1974, the cost share of labor was 53.3 percent while the price of labor was relatively low at that time. The differences between cost structures suggest that the railroad industry has experienced a rapid change in many respects and cost studies based on data of earlier years may no longer be valid for policy making.

- All firms have similar cost structures as the coefficients of variation are small among firms and between years.
- The coefficient of variation of the fuel cost share is relatively high. The reasons for this high variation are probably that the fuel cost share is directly related to traffic density, the efficiency of locomotives, and the terrain over which the trains operate rather than the restriction of the production technology. Hence, firms with high traffic density or operating over mountain ous terrain have a higher fuel cost share.

<u>Own price elasticities</u>

Table 8.6 presents the results of input own price elasticities and their coefficients of variation. Input own price elasticity measures the relative amount change of input use with respect to the relative change of its own price. The following points can be drawn based on Table 8.6:

- Capital has the highest own price elasticity. The reason is probably because capital is a substitute not only for labor but also for fuel. A one percent increase in the price of capital will result in a 0.86 percent decrease in the use of capital. The interpretation for labor is that a one percent increase of labor price will result in a decrease of 0.6 percent in the use of labor.

- Fuel is inelastic to its own price change. This is probably because the fuel cost share is relatively low and fuel consumption depends on current traffic density, the efficiency of locomotives, and the terrain of the road rather than short run fuel prices.
- The coefficient of variation of fuel is relatively high. The estimated own price elasticity of fuel ranges from -0.39 to 0.07 in 1981. This wide range in cross section data may indicate that the railroad companies operate over different types of terrain.
- Capital price elasticity and labor price elasticity are more homogeneous among firms. Most rail labor agreements are industry wide and capital is obtained in the national capital markets. This is consistent with the conclusion that firms production structure are similar.
- The differences between 1980 and 1981 own price elasticities are not significant.

Table 8.6 Estimated own price elasticities of the railroad industry based on the translog cost model

Year	Capital	Labor	Fuel
1980	-0.842 (6.9)[a]	-0.551 (10.5)	-0.249 (55.0)
1981	-0.849 (7.2)	-0.604 (10.8)	-0.293 (46.5)

[a] Numbers in brackets are percent coefficients of variation.

Summary of the results of the translog model

The results of the translog model can be summarized as follows:

1. The translog cost model is a suitable functional form for the cost estimation of the railroad industry as all economic regularity conditions are satisfied.
2. Cost behavior is a combined result of current input prices, current output level, and current firm size. Large firms usually have lower average costs. However, small size firms with high traffic density may very well have lower average costs than large firms with low traffic density.
3. The estimated average costs per net ton-mile of the railroad industry are 3.34 cents and 3.86 cents per net ton-mile in 1980 and 1981 respectively.
4. The estimated returns to firm size of the industry are 0.05 and 0.04 in 1980 and 1981 respectively.
5. The estimated returns to traffic density of the industry are 0.36 in both 1980 and 1981. The estimated minimum efficient traffic density of the industry is 7.2 million net ton-miles per route mile.
6. The estimated returns to average length of haul of the industry is 0.10.
7. All firms have similar cost structure and hence production structure.
8. Small size firms have more elastic returns to traffic density and returns to firm size.

9. All firms can reduce their average costs with increased traffic density.
10. All but four large firms can reduce their average costs by increasing firm size for the current traffic density level.
11. A total derivative of the translog cost function provides a more realistic estimation of cost behavior since practically it is not possible to expand firm size without changing traffic density and average length of haul. The results indicate that a one percent simultaneous increase of traffic density, firm size, and length of haul will lower 0.51 percent of average costs of the railroad industry in 1981.
12. Technology developments between 1980 and 1981 are not significant.
13. Labor-capital and fuel-capital are substitute inputs. Labor-fuel are more likely to be complementary inputs.
14. Capital and labor demand are more elastic to their own price change.
15. Fuel is less elastic to own price change. The use of fuel is more likely determined by traffic density, the efficiency of locomotives, and the terrain situation of the road.
16. The railroad industry has excess capacity for current traffic density level as the direction of the estimated optimal size for the railroad industry suggests that average costs would decline if the size of the firms decline.

The Results of the Generalized Leontief Cost Model

Table 8.7 presents the test results of the generalized Leontief cost model. The following conclusions can be drawn based on Table 8.7:

- Symmetry across input demand equations is tested for the compatibility between the data and economic regularity conditions prior to the estimation of the constrained generalized Leontief cost model. The results indicate that the symmetry restriction is rejected by the unconstrained generalized Leontief cost model. The symmetry property of a cost model rests on the substitution symmetry among input factors of the underlying cost and production theory. The rejection of symmetry implies that the generalized Leontief cost model is not a suitable functional form to "globally" represent the cost structure of the railroad industry. However, as the generalized Leontief model is used as a local approximation of an arbitrary cost function at the second order level, one may not expect the restriction of symmetry to hold because the higher order terms are ignored by the model. By ignoring the higher order terms, the estimated generalized Leontief cost model will inherently result in truncation errors. This will limit the use of the generalized Leontief cost model in extrapolating outside the data range. Therefore, the conclusions are: 1) the generalized Leontief model can not globally represent the railroad cost function; and 2) the ability to extrapolate outside the data range is limited.
- The purpose of the homothetic production structure test is to

Table 8.7 The test results of the generalized Leontief cost model

Tests	F-values	Prob. > F
1. Test for symmetry across input demand functions.	57.30	0.000
2. Test for homotheticity in production structure. [a]	11.71	0.000
3. Test for reduced model[a]: ordinary Leontief model.	8.41	0.000

[a] The restriction of symmetry across input demand equations are imposed.

determine whether all the second order output level trems equal zero. The generalized Leontief cost model can be written as a separable function in output and input prices if all the second order output level terms equal zero. The test results indicate that all the second order output level terms do not equal zero. Hence, the production structure of the railroad industry is not homothetic based on the generalized Leontief model.

- For the generalized Leontief model, a nonhomothetic production structure also implies the production structure is not constant returns to scale as the input-output ratio will depend on the output level.
- A generalized Leontief cost model will reduce to an ordinary Leontief cost model if all $b_{ij} = 0$ for input i $\neq$ input j. The results indicate that all b_{ij}'s are not equal to zero and hence, the generalized Leontief cost model is a more suitable functional form than the ordinary Leontief cost model.

For a well-behaved cost function, continuity and linear homogeniety in input prices are the only conditions imposed by the generalized Leontief cost function. All other regularity conditions, nonnegativity, monotonicity, concavity, and nondecreasing in output level will depend on the actual values of the estimated parameters. Table 8.8 present the estimated results of the generalized Leontief cost model. The conditions of nonnegativity and monotonicity are satisfied as all the estimated

Table 8.8 Estimates of the input demand equations of the generalized Leontief cost model

Equation	Labor	Capital	Fuel	Output	Traffic density	Average length of haul
Labor	0.227 (1.43)[a]	0.00297 (4.22)	0.027 (3.23)	$-4.56*10^{-7}$ (-1.04)	-0.033 (-2.49)	-0.00034 (-2.25)
Capital	0.00297 (4.22)	0.00327 (16.3)	$0.4*10^{-4}$ (3.16)	$1.83*10^{-10}$ (0.13)	$-0.94*10^{-4}$ (-2.05)	$-2.15*10^{-6}$ (-4.28)
Fuel	0.027 (4.22)	0.00004 (3.16)	$-0.28*10^{-2}$ (-1.64)	$-7.84*10^{-9}$ (-4.50)	$-0.28*10^{-2}$ (-1.64)	$1.76*10^{-6}$ (3.03)

$R^2 = 0.97$

[a] Numbers in brackets are t-ratios.

input demands based on Table 8.8 are positive. The condition of concavity is satisfied as all b_{ij} for $i \neq j$ are nonnegative. The nondecreasing-in-output condition is satisfied as the partial derivatives of the cost function with respect to output, i.e. returns to traffic density, are positive for all firms (refer to Table 8.9).

The suitability of the generalized Leontief cost model for estimating cost function of the railroad industry is summarized as follows:

1. The generalized Leontief model can not globally represent the railroad cost function and is limited in extrapolating outside the data range.
2. All economic regularity conditions of a well-behaved cost function are satisfied by the results of the constrained generalized Leontief cost function. Hence, the generalized Leontief cost function can locally represent the cost function of the railroad industry.
3. The generalized Leontief cost model is flexible in specifying a nonhomothetic production structure.
4. The ordinary Leontief cost function is rejected as a suitable functional form.
5. The overall weighted R^2 is 97 percent although the symmetry restriction is rejected.

In summary, the generalized Leontief cost model is accepted as a suitable functional form to locally represent the cost function of the railroad industry.

Table 8.9 presents the estimated average costs per net ton-mile, returns to traffic density, returns to firm size, and returns to average length of haul for each individual firm as well as current firm size and traffic density. The following is an analysis of the results in Table 8.8 and Table 8.9:

Estimated average cost

- The estimated weighted average costs per net ton-mile for the railroad industry industry were 3.67 cents in 1980 with 30.8 percent coefficient of variation and 3.90 cents in 1981 with 31.1 percent coefficient of variation. Actual average costs were 3.55 cents and 4.03 cents in 1980 and 1981 respectively. Large size firms generally had lower average costs than small firms. The correlation coeficient between the estimated average costs and firm size is -0.29. However, small size firms with high traffic density may very well have lower average costs than large firms with low traffic density. For example, the estimated average cost of the Colorado & Southern Ry. Co. (CS) was only 2.08 cents per net ton-mile in 1981. The CS had only 678 road miles, but its traffic density was as high as 12.5 million ton-miles per road mile. Hence, cost behavior is the result of a combination of firm size and traffic density.

Returns to traffic density

- Using equation (5.19), returns to traffic density are estimated for individual firms. All firms have positive returns to traffic density which means all firms lowered their average costs by

Table 8.9 Current firm size and traffic density and estimated average costs, returns to traffic density, returns to firm size, returns to average length of haul for each individual firm based on the generalized Leontief cost model for Class I railroad companies, 1980 and 1981

Year	Railroad company	Current firm size in road miles	Current traffic density in million ton-miles per mile	Estimated average cost in cents per net ton-miles	Estimated returns to traffic density	Estimated returns to firm size	Estimated returns to average length of haul
1980	ATSF	12,161	6.0	2.8	0.15	0.0038	0.35
	BO	5,280	4.4	3.8	0.07	0.0008	0.09
	BLE	205	10.8	3.3	0.19	0.0001	0.03
	BM	1,393	1.8	3.6	0.02	0.0001	0.05
	BN	27,361	5.1	2.6	0.15	0.0083	0.36
	CO	4,754	6.2	3.7	0.11	0.0011	0.12
	CNW	9,379	3.1	5.2	0.06	0.0010	0.14
	CMSP	3,901	3.0	3.7	0.04	0.0003	0.12
	CLIN	296	13.7	2.9	0.43	0.0002	0.11
	CS	678	10.7	2.1	0.31	0.0005	0.16
	CRS	18,902	4.4	3.1	0.07	0.0028	0.14
	DH	1,746	2.2	4.3	0.03	0.0001	0.15
	DRGW	1,848	6.0	4.0	0.12	0.0005	0.14
	DTI	540	2.8	5.8	0.04	0.0001	0.07
	DMIR	441	5.1	4.2	0.07	0.0001	0.02
	EJE	201	3.2	3.1	0.02	0.0000	0.01
	FEC	492	5.9	2.9	0.09	0.0001	0.09
	FWD	1,181	6.5	3.0	0.18	0.0005	0.19
	GTW	929	3.7	5.4	0.07	0.0001	0.08
	ICG	8,566	3.8	5.2	0.07	0.0011	0.14
	KCS	1,663	5.9	3.8	0.11	0.0004	0.11
	LN	6,570	5.9	3.8	0.12	0.0016	0.13
	MKT	2,175	3.8	2.8	0.05	0.0002	0.09
	MP	11,521	5.2	3.5	0.10	0.0024	0.20

Table 8.9 (continued)

Year	Railroad company	Current firm size in road miles	Current traffic density in million ton-miles per mile	Estimated average cost in cents per net ton-miles	Estimated returns to traffic density	Estimated returns to firm size	Estimated returns to average length of haul
1980	NW	7,448	6.5	3.2	0.12	0.0020	0.15
	PLE	270	5.3	7.9	0.10	0.0001	0.03
	SLSW	2,448	4.4	3.4	0.12	0.0006	0.26
	SCL	8,740	4.2	4.5	0.08	0.0013	0.09
	SOO	4,445	2.3	4.4	0.04	0.0004	0.16
	SP	10,966	6.0	3.2	0.15	0.0032	0.30
	SRS	10,210	5.3	3.6	0.11	0.0022	0.16
	UP	8,614	9.2	2.1	0.26	0.0048	0.51
	WM	1,180	1.8	6.0	0.02	0.0001	0.04
	WP	1,435	3.2	5.0	0.06	0.0002	0.19
1981	ATSF	12,366	6.1	2.6	0.16	0.0040	0.38
	BO	5,230	4.4	3.4	0.08	0.0008	0.11
	BLE	205	10.3	2.9	0.23	0.0001	0.04
	BM	1,317	1.7	3.4	0.02	0.0001	0.05
	BN	27,374	5.7	2.5	0.14	0.0077	0.39
	CO	4,856	5.9	3.4	0.13	0.0013	0.13
	CNW	8,256	3.4	5.0	0.06	0.0012	0.14
	CMSP	3,925	2.7	3.4	0.05	0.0004	0.12
	CLIN	296	14.8	2.9	0.40	0.0002	0.11
	CS	678	12.5	2.3	0.25	0.0004	0.14
	CRS	18,420	4.3	2.9	0.08	0.0032	0.14
	DH	1,722	2.0	4.0	0.04	0.0001	0.16
	DRGW	1,802	6.4	3.8	0.12	0.0005	0.15
	DTI	623	2.4	5.4	0.05	0.0001	0.07
	DMIR	436	5.1	3.9	0.08	0.0001	0.02

Table 8.9 (continued)

Year	Railroad company	Current firm size in road miles	Current traffic density in million ton-miles per mile	Estimated average cost in cents per net ton-miles	Estimated returns to traffic density	Estimated returns to firm size	Estimated returns to average length of haul
1981	EJE	201	2.7	2.7	0.04	0.0000	0.01
	FEC	492	5.8	2.8	0.11	0.0001	0.10
	FWD	1,181	8.3	3.1	0.14	0.0003	0.17
	GTW	972	3.8	5.0	0.07	0.0001	0.08
	ICG	7,963	3.8	4.9	0.08	0.0013	0.15
	KCS	1,663	5.9	3.6	0.12	0.0004	0.11
	LN	6,538	6.2	3.7	0.12	0.0016	0.14
	MKT	2,174	3.9	2.6	0.05	0.0003	0.11
	MP	11,272	5.2	3.3	0.11	0.0027	0.20
	NW	7,803	6.3	2.9	0.14	0.0022	0.16
	PLE	270	4.8	7.5	0.11	0.0001	0.03
	SLSW	2,384	5.6	3.6	0.09	0.0005	0.21
	SCL	8,563	4.2	4.3	0.08	0.0015	0.09
	SOO	4,433	2.2	4.1	0.04	0.0004	0.19
	SP	10,962	5.9	2.9	0.17	0.0036	0.34
	SRS	10,057	5.3	3.5	0.11	0.0024	0.16
	UP	9,096	8.2	1.8	0.35	0.0062	0.62
	WM	1,175	1.6	5.7	0.03	0.0001	0.04
	WP	1,435	2.9	4.6	0.07	0.0002	0.22

increasing the output level on their existing road miles..

- The weighted average returns to traffic density of the railroad industry were 0.12 and 0.11 in 1980 and 1981 respectively.
- The relationship between firm size and returns to traffic density is not clear as the estimated correlation coefficient between firm size and returns to traffic density is not significant.
- The estimated returns to traffic density for individual firms ranges from 0.02 to 0.40.

Returns to firm size

- Using equation (5.20), returns to firm size are estimated for each individual firm. All the firms indicate positive returns to firm size which means all firms lowered their average costs by increasing their firm size.
- The weighted average returns to firm size of the railroad industry were 0.001 in both 1980 and 1981.
- Large firms had higher returns to firm size. The estimated correlation coefficient between firm size and returns to firm size was 0.89. This is probably because returns to firm size is a function of input prices, output level, and average costs. As large firms may have lower input prices, lower average costs, and higher output levels, returns to firm size are higher for the large size firms than for the small size firms. However, the estimated returns to firm size is relatively small for all firms. The range of the estimated returns to firm size was 0.00001 to

0.0083. It is more likely that the railroad industry has small or near constant returns to firm size.

Returns to average length of haul

- Using equation (5.21), returns to average length of haul are estimated for each individual firm. The results indicate positive returns to average length of haul for all firms which means all firms lowered their average costs per ton-mile by increasing their average length of haul.
- The weighted average returns to average length of haul of the railroad industry were 0.15 and 0.16 in 1980 and 1981 respectively
- Large firms usually had higher returns to average length of haul as the estimated correlation coefficient between firm size and returns to average length of haul was 0.58. This is probably because the savings from long haul movements are directly related to the average length of haul. The return to a one percent increase in average length of haul for large firms is greater than that for small firms and hence large firms have higher returns to average length of haul. This result is consistent with the assumption that large firms usually have longer hauls than small firms.
- The range of the estimated returns to average length of haul is from 0.01 to 0.61.

Optimal firm size and minimum efficient traffic density

- The optimal firm size can be estimated by taking a partial derivative of the average cost function with respect to output while holding traffic density constant. The minimum efficient traffic density can be estimated by taking a partial derivative of the average cost function with respect to output while holding firm size constant. However, in the generalized Leontief cost model, average cost is a linear function of output since total cost is a quadratic function of output. Therefore, the first order condition of the average cost function with respect to output is not a function of output level and hence the optimal firm size and minimum efficient traffic density can not be estimated from the generalized Leontief cost model.

Interaction of returns to firm size, traffic density, average length of haul

Equation (5.22) is applied to the estimated generalized Leontief cost model to allow a simultaneous change of traffic density, firm size, and average length of haul. The net effect of a simultaneous change of one percent of traffic density, firm size, and average length of haul of the railroad industry is:

$$\begin{aligned} d(AC) &= (RD)\ dD + (RS)\ dS + (RN)\ dN \\ &= (0.12)\ (1.0) + (0.001)\ (1.0) + (0.16)\ (1.0) \\ &= 0.281 \end{aligned}$$

The estimated net effect indicates that a one percent increase in traffic density, firm size, and average length of haul for the railroad industry will result in a 0.281 percent decrease in average cost per net ton-mile. Therefore, these estimates suggest that fewer but larger firms operating fewer total miles of track would have had lower total costs than the 1980 and 1981 cost level.

Production structure of the railroad industry

Elasticities of substitution among input factors are estimated for the railroad industry based on equation (5.17). Table 8.10 presents the estimated results and the following points can be drawn from Table 8.10:

- All input factors are substitutes for one another as all the estimated elasticities of substitution are positive.
- Capital-fuel and labor-fuel are less substitutable than capital-labor.
- The production structure in 1980 and 1981 were similar.

Cost structure of the railroad industry

Table 8.11 presents the estimated cost structure of the railroad industry. The following points can be drawn from Table 8.11:

- The major cost component is labor. About 46 percent of total costs were spent for labor. Capital and fuel shares were 43 percent and 11 percent respectively.
- The coefficient of variation of fuel cost share is relatively high. The reason for this high variation is because that fuel cost share is directly affected by traffic density, fuel efficiency of locomotives, and terrain. Also, firms with higher traffic density would have a higher fuel cost share.

Own price elasticity

Table 8.12 presents the estimated own price elasticities of labor, capital, and fuel. The following points can be drawn from Table 8.12:

Table 8.10 Estimated elasticities of substitution among input factors of the railroad industry based on the generalized Leontief cost model

Year	Capital-labor	Capital-fuel	Fuel-labor
1980	1.174 (28.4)[a]	0.002 (15.6)	0.205 (23.2)
1981	1.096 (30.0)	0.002 (13.6)	0.210 (22.5)

[a] Numbers in brackets are coefficients of variation.

Table 8.11 Estimated cost structure of the railroad industry based on the generalized Leontief cost model

Year	Labor share	Capital share	Fuel share
1980	0.467 (6.9)[a]	0.415 (12.4)	0.118 (20.1
1981	0.450 (7.3)	0.443 (11.8)	0.107 (22.0)

[a] Numbers in brackets are coefficients of variation.

Table 8.12 Estimated own price elasticities of input demand of the railroad industry based on the generalized Leontief cost model

Year	Labor	Capital	Fuel
1980	-0.574 (22.4)[a]	-0.004 (30.6)	-0.941 (18.4)
1981	-0.571 (22.1)	-0.004 (32.9)	-0.915 (15.5)

[a] Numbers in brackets are coefficients of variation.

- Fuel demand is more elastic to its own price than capital and labor. This may reflect possible energy saving programs carried out by the railroad industry.
- Although the coefficient of variation of capital own price elasticity is relatively high, the range of capital own price elasticity is from 0.001 to 0.009.

Summary of the results of the generalized Leontief cost model

The results of the generalized Leontief cost model are summarized as follows:

1. All economic regularity conditions of a well-behaved cost function are satisfied with the generalized Leontief model.
2. The estimated average costs per net ton-mile of the railroad industry were 3.67 cents and 3.90 cents in 1980 and 1981 respectively.
3. The estimated returns to traffic density of the railroad industry were 0.12 and 0.11 in 1980 and 1981 respectively. All firms indicate a positive returns to traffic density.
4. The estimated returns to firm size of the railroad industry were 0.001 in both 1980 and 1981. All firms indicate a positive returns to firm size.
5. The estimated returns to average length of haul for the railroad industry were 0.15 and 0.16 in 1980 and 1981 respectively. All firms indicate a positive returns to average length of haul.
6. A one percent simultaneous increase of traffic density, firm size, and length of haul would have lowered the average costs of

7. All input factors are substitutes for one another, but capital-fuel and labor-fuel are less substitutable.
8. The major cost component is labor expenditure.
9. Capital demand is less elastic to its own prices and fuel demand is more elastic to its own prices.
10. Both production and cost structure were similar in 1980 and 1981.
11. The relationship between firm size and returns to traffic density is not clear, but firms with large size usually had higher returns to firm size and returns to average length of haul.
12. Optimal firm size and minimum efficient traffic density are not estimable for the generalized Leontief cost model as the first order condition of the average cost function is not a function of output level in the generalized Leontief cost model.
13. As all firms have positive returns to traffic density and returns to firm size, a decreasing long run average cost function is expected based on the results of generalized Leontief model.

A Comparison between the Results of the Translog Cost Model and the Generalized Leontief Cost Model

Cave and Christensen [9] pointed out that, theoretically, one can not tell if the translog cost model is better than the generalized Leontief cost model. Both models provide a second order approximation of an arbitrary cost function and are referred as flexible functional forms as no prior restrictions on the elasticities of substitution among input factors are imposed. However, the generalized Leontief cost model is more accurate when the input elasticities of substitution are small and the translog model is preferable when the input elasticity of substitution are high. As the railroad industry presumably has some excess capacity for the time being, one might expect the input elasticities of substitution are relatively small and hence the generalized Leontief cost model may be preferred.

Nevertheless, this study found that the curvature of average cost with respect to output under these two cost models are quite different. The specification of the translog cost model states that total cost in logarithms is a U-shaped quadratic function with respect to output in logarithms. As $\ln(AC) = \ln(TC/Y) = \ln(TC) - \ln(Y)$, a U-shaped quadratic total cost function in logarithm implies that its average cost in logarithms is also a U-shaped quadratic function with respect to output in logarithms. The specification of the generalized Leontief cost model, on the other hand, states that total cost is a U-shaped quadratic function with respect to output as well. But its average cost will reduce to a linear function with respect to output when the average cost is derived by dividing total cost by its output. A linear average cost function may be less accurate than a quadratic average cost function in estimating the cost structure of the railroad industry and will not permit the estimation of either optimal firm size or minimum traffic density; however, the estimated optimal firm size and minimum traffic density have limited meanings. Hence, the translog model may be more accurate than the generalized cost model based on the assumption of the curvature of average cost. In summary, one still can not be sure which model is better and hence further analysis is made of both models.

Table 8.13 presents a comparison between the results of the translog cost model and generalized Leontief cost model. The following conclusions can be drawn based on Table 8.13:

- Both the translog and generalized Leontief models are limited in extrapolating outside the data range, as tests of compatibility to symmetry and homogeneity conditions are either rejected or weakly accepted.
- When symmetry and homogeneity conditions are imposed, both models perform equally well in terms of R^2 and both models are associated with a well-behaved cost function.
- The estimated weighted average costs of the translog model were 3.34 cents per ton-mile and 3.86 cents per ton-mile in 1980 and 1981 respectively. The estimated weighted average cost of the generalized Leontief model were 3.67 cents per ton-mile and 3.90 cents per ton-mile in 1980 and 1981 respectively. The actual average costs were 3.55 cents per ton-mile and 4.03 cents per ton-mile in 1980 and 1981 respectively.
- Both models indicate relatively high returns to traffic density.

Table 8.13 A comparison between the results of railroad cost estimation of the translog cost model and generalized Leontief cost model

Result	Translog cost model	Generalized Leontief cost model
Linear homogeneity in input prices,	Accepted at 99 percent level	Automatically satisfied
Symmetry across input share or demand equations,	Accepted at 99 percent level	Rejected
Concavity, monotonicity, non-decreasing, and nonnegativity,	Satisfied	Satisfied
Estimated weighted average costs:		
1980	3.34 cents/net ton-mile	3.67 cents/net ton-mile
1981	3.86 cents/net ton-mile	3.90 cents/net ton-mile
Returns to traffic density,	0.36 for the industry	0.12 for the industry
Returns to firm size,	0.04 for the industry	0.001 for the industry
Returns to average length of haul,	0.10 for the industry	0.15 for the industry
Estimated minimum efficient traffic density	7.1 million ton-miles/mile	---
Interaction of returns to firm size, traffic density, and average length of haul,	0.51	0.28

Table 8.13 (continued)

Result	Translog cost model	Generalized Leontief cost model
Estimated elasticities of substitution among inputs:		
Capital-labor	1.57 (0.029)[a]	1.14 (0.285)
Capital-fuel	0.75 (0.072)	0.02 (0.0007)
Fuel-labor	-0.10 (0.370)	0.21 (0.069)
Estimated cost shares:		
Labor	48	46
Capital	40	43
Fuel	12	11
Estimated own price elasticities:		
Labor	-0.578 (0.383)	-0.573 (0.127)
Capital	-0.845 (0.402)	-0.004 (0.001)
Fuel	-0.271 (1.428)	-0.928 (0.218)
Overall R^2	0.96	0.97

[a] Number in bracket is standard error.

However, the result of the translog model further indicate that there is a negative relationship between returns to traffic density and firm size. This result is consistent with the cost behavior of a U-shaped long run average cost curve as shown in Figure 4.1.

- The results of the translog model indicate that small firms have higher returns to firm size than large firms while the results of the generalized Leontief model indicate that larger firms have higher returns to firm size than smaller firms. However, both model indicate relatively low returns to firm size.
- The results of both models indicate relatively high returns to average length of haul. The results of the generalized Leontief further indicate that there is a positive relationship between returns to average length of haul and firm size; that is, large firms have higher returns to length of haul than smaller firms. This seems reasonable because larger firms have the advantage of longer length of haul.
- The results indicate that a simultaneous increase of traffic density, firm size, and average length of haul lowered the average costs by 0.51 percent and 0.28 percent respectively.
- The estimated elasticities of substitution between labor and capital are greater than unity with relatively small variance in both models indicating that labor and capital are highly substitutable for each other. Capital and fuel are less substitutable since the estimated elasticities of substitution

between capital and fuel are less than unity. The relatively small variances indicate that the elasticities are significantly different from zero although the estimated elasticity of substitution of capital and fuel of the generalized Leontief model is relatively small. Fuel and labor are complementary inputs in the translog model but the relatively large standard error indicates that this relationship is indeterminate. The generalized Leontief model results indicate that fuel and labor are slightly substitutable with relatively small variances.

- The results of both models indicate that labor costs are the major component of total costs while the fuel cost shares are the smallest cost component of total costs.
- The estimated labor price elasticities are -0.57 in both models. However, the translog estimate has a relatively large variance and is significant only at the 90 percent level. Both models indicate that the capital own price elasticity is less than unity with relatively small variances. The estimated capital price elasticity of the generalized Leontief model is relatively small, but is statistically significant. The estimated fuel price elasticity is less than unity in both models. However, the variance of the translog model is relatively large indicating that the estimate is not significantly different from zero. The conclusion is that all inputs are price inelastic since all estimated input price elasticities are less than unity.

The basic conclusions from the results of both models are as follows:

1. There are substantial returns to traffic density for the railroad industry.
2. There are substantial returns to average length of haul for the railroad industry.
3. There are small returns to firm size where firm size is measured by road miles of track.
4. A simultaneous increase of traffic density, firm size, and average length of haul lowers the average costs of the railroad industry.
5. Capital and labor are highly substitutable as the estimated elasticities of substitution are greater than unity with relatively small variances.
6. Labor and fuel, and capital and fuel are less substitutable than capital and labor.
7. The major cost component is labor.
8. All input price elasticities of demand are less than unity.
9. The translog model suggests that: a) returns to traffic density will be exhausted at 7.1 million net ton-mile per road mile; and 2) there exists excess capacity in the railroad industry.
10. The differences between the results of the translog cost model and generalized Leontief cost model are relatively small. However, the estimated input own price elasticities and elasticity of substitution between capital and fuel of the translog model are more reasonable than that of the generalized Leontief cost model. Hence, the translog cost model may be a better fit than the generalized Leontief cost model for the 1980

and 1981 railroad industry cost structure.

A Comparison with other Studies

This study differs from previous railroad cost studies in the following respects:

1. The data used by all previous studies are relatively old. Most of the data are from 1968 to 1974 operations. The data used in the present analysis are from 1980 and 1981 operations. Policy implications based on old cost studies need to be retested for current policy making as the railroad industry experienced rapid structural change in the 1970s.
2. Most previous studies used relatively more restrictive models, such as the Cobb-Douglas model. A more restrictive model is less powerful in estimating the current cost structure than a less restrictive model.
3. Most previous studies failed to include input prices as explanatory variables while the present study includes input prices. A model with the assumption of constant input prices can not estimate the input elasticities of substitution and hence the production structure.
4. Some older studies used the translog model, however, none of these studies included an analysis of the net effects on costs of simultaneous changes in several variables.
5. None of the older studies tested the compatibility between the railroad data and the model.
6. None of the older studies used flexible models other than the translog model.

7. None of the older studies compared the implications between two different models based on the same data set.

A comparison of the results of our study with previous studies yields the following conclusions:

1. All but one previous study found the railroad industry has substantial returns to traffic density. Friedlaender and Spady [18] found negative returns to traffic density. The results of the present analysis indicates that the railroad industry has substantial returns to traffic density.
2. All previous studies concluded that the railroad industry has either small returns to firm size or constant returns to firm size. The results of this analysis indicate that the railroad industry has slightly increasing returns to firm size.
3. All previous studies found that the railroad industry has substantial returns to average length of haul. The results of this analysis also indicate substantial returns to average length of haul.
4. All previous studies using the Cobb-Douglas model assume that: a) input elasticities of substitution are all unity; and b) production structure is homothetic. Our results indicate that input elasticities of substitution are not all unity and production structure of the railroad industry is not homothetic.
5. All previous studies using linear models assume that: a) all input prices are constant; and b) the production structure is presupposed rather than estimated. Our data indicate that there

are significant differences among firms' input prices, and the production structure of the railroad is estimated.

6. Most previous studies indicate substantial cost saving potential from restructuring the railroad industry as it existed during the 1968-74 period. There was a major restructuring of the railroad industry during the decade of the 1970s. Nevertheless, our results suggest that there were still significant cost savings potential from further restructuring of the railroad industry through increased traffic density and length of haul for the years of 1980 and 1981. This is most likely to be achieved by reducing the number of railroad companies and miles of track. Most agricultural interests believe that they are better served by a railroad system consisting of many firms operating on a large number of miles of track. The results of this study suggest that further analysis is needed to evaluate the trade-off between further restructuring to obtain a lower cost railroad system consisting of fewer but larger firms operating on fewer miles of track and higher cost railroad system consisting of a larger number of small competing firms operating on more miles of track.

CHAPTER IX. SUMMARY AND CONCLUSIONS

In February, 1983, the Interstate Commerce Commission (ICC) published a decision in Ex Parte No. 347 (Sub-No. 1), Coal Rate Guidelines, Nationwide, proposing a maximum railroad rate policy applicable to "captive" coal traffic to achieve the basic objective of revenue adequacy in accordance with the 4R Act. Revenue adequacy is defined as a level of earnings sufficient to enable a carrier to meet all of its expenses, retire a reasonable amount of debt, cover plant depreciation and obsolescence, and earn a return on investment adequate to attract new capital. In 1983, a 15.7 percent return on net investment was required to achieve revenue adequacy. The railroad industry, however, earned only 3.1 percent return on net investment in 1983. Under the proposed Coal Rate Guidelines, rail carrier pricing of so called "captive" coal traffic would subject to the following four upward constraints:

1. A coal shipper could not be charged more than the "stand-alone cost" of serving its traffic.
2. Captive shippers or receivers would not be required to bear the cost of obvious management inefficiencies.
3. Carriers would generally not be permitted to increase their rates on "captive" coal traffic by more than 15 percent in a single year (after allowing for inflation).
4. Until a rail carrier achieves revenue adequacy, it would be free to adjust its rate unless it violates one of the three constraints listed above.

If the proposed Coal Rate Guidelines are implemented on coal traffic, it is expected that similar guidelines will be applied to other so called "captive" commodities, such as grains, fertilizer, and chemical goods.

The Coal Rate Guidelines proposed by the ICC imply that the railroad industry can raise rates on the so called "captive" coal to the level required to achieve the goal of revenue adequacy of the railroad industry. The Guidelines emphasize the inelastic demand characteristic of the "captive" coal, but ignore the cost side and the structure of the railroad industry as a crucial part in achieving railroad revenue adequacy.

To estimate the potential contribution of the cost and structure of the railroad industry in achieving revenue adequacy, two flexible functional forms, the translog and generalized Leontief models were used to estimate railroad cost behavior under different scenarios. The conclusions from the results of the estimated translog and generalized Leontief cost models are:

1. The railroad industry has substantial returns to traffic density. This means that average costs decline as more traffic is put on the existing track or existing traffic levels are carried on fewer miles of track.
2. The railroad industry has substantial returns to average length of haul. This means that average costs decline as the length of haul by each railroad increases.

3. The railroad industry has small returns to firm size.
4. The net effect of returns to density, length of haul, and firm size is large. This means that a simultaneous increase in traffic density, length of haul, and firm size results in a sharp decrease in average costs.
5. The railroad industry had excess capacity for 1980-81 traffic levels.
6. Capital and labor are highly substitutable while labor and fuel and capital and fuel are less substitutable.
7. Labor costs are the major component of total railroad costs.
8. All input price elasticities are less than unity.

The policy implications of these results for shippers who are concerned about higher rail rates required by a national policy to achieve railroad revenue adequacy are as follows:

1. The existence of returns to firm size and returns to average length of haul suggest that continued restructuring the railroad industry to a larger average firm size and fewer number of firms than existed in 1980-81 will lower the average costs of the railroad industry. One alternative to achieve a higher average firm size and fewer number of firms is through mergers. The advantages of mergers result largely from the improved train operations, better equipment utilization, more efficient use of facilities, longer average length of haul, access to more markets, and reduced labor requirements. However, mergers of similar railroads that do not substantially affect operations

or do not eliminate low density lines are not likely to result in lower costs since mergers may result in managerial diseconomies of size. Hence, a case by case study is needed to ensure that railroad mergers do indeed result in lower costs.

2. The existence of increasing returns to traffic density means that the costs of rail service on high density lines are lower than on low density lines. This suggests that continued elimination of 1980-81 light traffic density lines will reduce railroad costs and at the same time increase railroad earnings and reduce railroad investment. Thus, increased density will contribute to railroad revenue adequacy.
3. Intermodal cost comparisons should be based on the costs of the specific railroad lines over which the traffic moves rather than on the average costs of the railroad industry. The strategy for pricing for intermodal competition with the truck or barge industries should be based on the costs of individual lines rather than on the current average costs. This type of costing will help attract more traffic on low cost lines thus increasing traffic density which will further decrease average costs.
4. The production structure of the railroad industry indicates that capital and labor are highly substitutable while capital and fuel, and labor and fuel are less substitutable. The ability to substitute among factors implies that in dealing with heterogeneous inflation, firms should be able to adjust their input

demands to minimize their production costs. In the past decades, the railroad industry significantly reduced the labor input and developed energy saving techniques in responding to the rapid change in fuel prices. The 1980-81 cost structure indicates that labor costs are still the major cost component of total costs. A one percent increase of labor prices will cause a much large increase in total costs than a one percent increase of capital or fuel prices. Therefore, the railroad industry may need to use more capital if labor prices increase more rapidly than capital or fuel prices. An alternative to reducing the labor input is to modify existing labor work rules so that capital would become less substitutable for labor.

5. The existence of excess capacity implies that the railroad industry may lower its average costs if the size of the industry declines from the 1980-81 levels. This suggests that continued reduction in the size of the railroad plant will lower average costs and reduce the level of rate increases required to allow revenue adequacy.

These cost saving policies reduce the variable costs, fixed costs, and net investment in equation (1.1). A reduction of variable costs and fixed costs will increase the numerator in equation (1.1) while a reduction of net investment will decrease the denominator in equation (1.1). Both changes will result in an increase of returns on investment. Hence, a cost saving policy will, in part, help achieve the goal of revenue adequacy for the railroad industry rather than relying entirely on rate increases on traffic with a highly inelastic demand for rail transportation.

In 1974, the railroad industry had 67 Class I railroads with 327,285 miles of track and 525,177 employees. In 1981, the railroad industry consisted of 35 Class I railroads with 278,000 miles of track and 436,397 employees. Hence, the results of this study indicate these major changes in the railroad industry have not exhausted the cost saving potential from restructuring the railroad industry. If revenue adequacy of the railroad industry remains a national goal as specified in the 4R and Staggers Rail Act of 1980, further restructuring the 1980-81 railroad industry would reduce the level of rates required to achieve revenue adequacy.

Finally, as this study is based on 1980 and 1981 data, the interpretation of the results is limited to the cost structure of these years. As the railroad industry has experienced rapid technological change, further research may be needed when new data become available. Moreover, the model specification can be further improved if less aggregate data are available.

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APPENDIX: THE DATA

Year	Railroad company	Number of employee	Total labor cost in million dollars	Freight labor cost in million dollars	Freight labor benefit in million dollars
1980	ATSF	34423	860.1	819.3	166.2
	BO	15995	372.1	356.1	82.6
	BLE	1234	31.5	30.0	10.8
	BM	3186	78.9	47.1	9.7
	BN	56540	1358.2	1246.7	299.1
	CO	19453	446.5	422.8	88.1
	CNW	14095	393.0	360.4	76.2
	CMSP	8443	207.2	179.2	41.2
	CLIN	831	21.4	22.2	5.2
	CS	893	21.8	16.9	3.5
	CRS	79574	1985.7	1503.2	333.9
	DH	1968	44.8	43.9	10.0
	DRGW	3600	100.3	94.5	21.2
	DTI	1317	32.6	31.8	7.2
	DMIR	1621	38.1	37.7	13.0
	EJE	2814	57.3	51.8	18.5
	FEC	1136	22.6	21.5	4.7
	FWD	1531	37.7	36.4	7.5
	GTW	4335	105.4	99.4	22.2
	ICG	16682	445.2	399.7	85.0
	KCS	3209	81.3	83.7	16.3
	LN	14459	369.5	375.8	87.1
	MKT	2740	74.2	71.4	14.6
	MP	0781	538.2	529.5	113.7
	NW	2137	521.0	506.3	117.8
	PLE	2069	49.8	47.7	9.8
	SLSW	4824	112.9	107.9	25.0
	SCL	9799	484.9	427.4	101.8
	SOO	4568	110.2	110.7	25.7
	SP	4727	854.0	779.4	175.7
	SRS	1202	494.0	504.8	118.1
	UP	7467	701.0	663.8	150.5
	WM	1144	27.7	28.4	7.6
	WP	2678	65.5	64.8	13.9

Year	Railroad company	Freight operating expense in million dollars	Freight fuel cost in million dollars	Fuel price in dollars per gallon	Capital price in percentage	Fixed charge in million dollars
1980	ATSF	1977.4	306.3	0.82	7.290	48.9
	BO	882.2	93.5	0.81	6.612	33.2
	BLE	74.6	5.3	0.85	6.751	2.3
	BM	111.4	11.7	0.83	4.654	2.2
	BN	3136.1	476.2	0.85	6.923	102.5
	CO	830.4	76.2	0.85	7.521	24.9
	CNW	868.6	110.8	0.86	10.218	36.0
	CMSP	460.5	48.1	0.82	6.080	35.3
	CLIN	65.9	11.7	0.78	9.047	4.8
	CS	121.5	25.1	0.85	5.591	2.2
	CRS	3643.9	338.1	0.85	5.528	121.1
	DH	118.7	15.2	0.89	7.794	5.7
	DRGW	234.6	47.6	0.85	8.308	7.2
	DTI	76.6	6.3	0.77	10.450	2.9
	DMIR	73.7	4.9	0.83	6.668	0.0
	EJE	93.8	4.2	0.83	3.566	1.0
	FEC	78.4	8.5	0.76	5.358	1.1
	FWD	117.6	16.7	0.84	6.930	1.0
	GTW	196.8	15.7	0.82	10.006	5.3
	ICG	946.8	115.1	0.83	10.610	49.1
	KCS	244.3	28.0	0.80	7.310	12.1
	LN	999.7	136.2	0.82	7.948	47.0
	MKT	210.5	27.0	0.78	3.771	11.2
	MP	1480.0	210.1	0.87	7.298	74.2
	NW	1214.1	142.4	0.82	6.579	36.0
	PLE	62.9	4.1	0.79	17.009	15.8
	SLS	266.4	37.0	0.86	8.037	14.6
	SCL	1111.4	136.6	0.81	8.464	52.0
	SOO	264.0	27.5	0.82	8.274	10.4
	SP	1986.5	259.5	0.79	8.195	87.5
	SRS	1345.5	183.8	0.80	7.730	51.8
	UP	1731.7	280.7	0.82	7.153	65.6
	WM	84.3	7.3	1.13	9.904	6.5
	WP	181.1	26.5	0.82	10.596	8.5

Year	Railroad company	Miles of road	Freight gross ton-mile in million	Passenger gross ton-mile in million	Freight net ton-mile in million	Net ton in million
1980	ATSF	12161	177677	0.0	73405	119.3
	BO	5280	52871	86.0	23219	89.9
	BLE	205	3119	0.0	2206	25.4
	BM	1393	5757	0.0	2448	13.2
	BN	27361	304297	419.0	140360	215.8
	CO	4754	58910	0.0	29419	106.5
	CNW	9379	69639	1216.0	29347	93.1
	CMSP	3901	27318	494.0	11631	34.6
	CLIN	296	7710	0.0	4060	24.0
	CS	678	14737	0.0	7230	27.4
	CRS	18902	195517	4925.0	83270	240.0
	DH	1746	8238	0.0	3820	10.2
	DRGW	1848	22735	172.0	11029	34.8
	DTI	540	3246	0.0	1512	8.8
	DMIR	441	4203	0.0	2237	47.7
	EJE	201	1181	0.0	637	17.8
	FEC	492	6153	0.0	2909	12.4
	FWD	1181	15403	0.0	7732	22.1
	GTW	929	9401	0.0	3449	17.7
	ICG	8366	67067	9.0	31991	98.2
	KCS	1663	20365	0.0	9916	38.9
	LN	6570	84104	0.0	38836	131.5
	MKT	2175	17109	0.0	8255	23.4
	MP	11521	126101	0.0	59843	140.8
	NW	7448	105864	15.0	48441	141.6
	PLE	270	2706	8.0	1443	22.0
	SLSW	2448	27401	0.0	10672	24.4
	SCL	8740	91725	0.0	37636	173.5
	SOO	4445	21241	0.0	10274	25.2
	SP	10966	164787	297.0	66226	114.7
	SRS	10210	130324	0.0	54554	160.9
	UP	8614	197368	70.0	78905	108.4
	WM	1180	3498	0.0	2122	19.6
	WP	1435	13422	0.0	4594	10.3

Year	Railroad company	Number of employee	Total labor cost in million dollars	Freight labor cost in million dollars	Freight labor benefit in million dollars
1981	ATSF	33605	911.3	898.6	215.1
	BO	15417	390.0	383.8	101.5
	BLE	1183	34.0	34.8	11.8
	BM	2955	78.2	49.8	12.9
	BN	52828	1391.4	1300.0	370.4
	CO	19270	488.2	479.5	108.9
	CNW	14345	420.7	390.7	91.8
	CMSP	7489	196.2	176.3	44.8
	CLIN	825	23.6	28.3	7.2
	CS	848	22.0	18.9	4.3
	CRS	70264	1846.4	1377.1	360.7
	DH	1829	45.0	43.9	11.8
	DRGW	3652	112.0	110.6	26.7
	DTI	1232	32.7	34.6	8.6
	DMIR	1530	40.9	41.7	14.6
	EJE	2359	56.4	52.1	19.8
	FEC	1195	25.0	25.7	6.3
	FWD	1671	43.5	43.2	10.3
	GTW	4070	116.5	111.6	27.4
	ICG	15670	448.8	411.9	100.5
	KCS	3166	85.6	90.3	20.2
	LN	13579	374.1	414.5	109.1
	MKT	2945	85.5	82.5	19.2
	MP	20830	579.7	578.9	143.3
	NW	21208	547.6	544.2	144.9
	PLE	1933	49.5	48.0	11.2
	SLSW	5228	134.5	130.0	32.6
	SCL	20132	533.9	458.6	122.1
	SOO	4304	112.3	112.8	29.5
	SP	33333	901.2	851.9	214.4
	SRS	20496	513.6	527.1	144.3
	UP	26215	720.1	691.1	177.7
	WM	1110	29.0	29.7	8.6
	WP	2668	69.8	71.7	16.7

Year	Railroad company	Freight operating expense in million dollars	Freight fuel cost in million dollars	Fuel price in dollars per gallon	Capital price in percentage	Fixed charge in million dollars
1981	ATSF	2220.0	357.8	0.98	7.290	63.5
	BO	993.7	108.0	1.03	6.612	33.9
	BLE	81.9	6.2	1.04	6.751	3.7
	BM	123.2	14.4	1.04	4.654	2.3
	BN	3412.4	546.7	0.98	6.923	131.3
	CO	936.9	86.5	1.04	7.521	29.6
	CNW	904.6	115.2	1.01	10.218	45.2
	CMSP	460.2	47.6	1.00	6.080	43.0
	CLIN	79.9	15.8	1.03	9.047	4.8
	CS	152.7	36.7	0.94	5.591	1.9
	CRS	3558.3	383.1	1.04	5.528	117.3
	DH	127.5	18.1	1.13	7.794	8.6
	DRGW	279.0	58.3	1.03	8.308	7.7
	DTI	86.9	9.0	1.00	10.450	2.9
	DMIR	90.2	6.0	1.02	6.668	0.1
	EJE	94.8	4.1	0.99	3.566	2.7
	FEC	93.1	12.0	1.01	5.358	1.6
	FWD	151.5	25.6	0.94	6.930	0.8
	GTW	228.0	20.8	1.05	10.006	5.7
	ICG	1012.8	124.4	1.01	10.610	58.8
	KCS	274.7	34.8	1.02	7.310	17.2
	LN	1144.1	171.3	1.03	7.948	52.7
	MKT	248.7	34.4	0.99	3.771	15.7
	MP	1660.2	244.1	1.05	7.298	86.3
	NW	1340.7	166.8	1.02	6.579	40.7
	PLE	71.5	5.5	1.07	17.009	11.8
	SLSW	335.6	50.6	1.00	8.037	12.6
	SCL	1234.9	158.2	1.01	8.464	57.6
	SOO	278.7	29.5	0.99	8.274	10.9
	SP	2225.5	288.8	0.93	8.195	80.8
	SRS	1451.2	212.8	1.00	7.730	55.2
	UP	1808.4	297.7	0.98	7.153	64.4
	WM	75.8	6.6	1.25	9.904	6.8
	WP	193.9	28.7	0.99	10.596	10.1

Year	Railroad company	Miles of road	Freight gross ton-mile in million	Passenger gross ton-mile in million	Freight net ton-mile in million	Net ton in million
1981	ATSF	12366	186974	0.0	75742	122.6
	BO	5230	53026	94.1	22969	93.3
	BLE	205	3044	0.0	2115	26.9
	BM	1317	5277	0.0	2250	12.4
	BN	27374	339684	410.3	156619	247.0
	CO	4856	58812	0.0	28768	105.1
	CNW	8256	66174	1165.9	28387	88.6
	CMSP	3925	24238	458.3	10618	31.9
	CLIN	296	8107	0.0	4373	26.0
	CS	678	16725	0.0	8485	30.8
	CRS	18420	185343	4870.9	79035	222.2
	DH	1722	7626	0.0	3496	9.2
	DRGW	1802	28882	160.4	11568	36.5
	DTI	623	3523	0.0	1508	8.6
	DMIR	436	4552	0.0	2216	47.9
	EJE	201	1069	0.0	547	15.4
	FEC	492	5734	0.0	2850	12.0
	FWD	1181	19001	0.0	9837	26.6
	GTW	972	10152	0.0	3742	18.8
	ICG	7963	60407	7.3	29968	94.8
	KCS	1663	20429	0.0	9880	38.4
	LN	6538	89661	0.0	40401	136.0
	MKT	2174	17392	0.0	8402	26.0
	MP	11272	129567	0.0	58299	132.2
	NW	7803	103537	15.4	48698	142.5
	PLE	270	2431	5.7	1303	19.5
	SLSW	2384	32575	0.0	13276	25.6
	SCL	8563	88333	0.0	36335	163.2
	SOO	4433	19709	0.0	9560	23.3
	SP	10962	161758	282.3	65171	117.2
	SRS	10057	124935	0.0	53157	152.4
	UP	9096	183153	53.9	74545	103.8
	WM	1175	3211	0.0	1869	17.7
	WP	1435	12245	0.0	4140	10.1